Span

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SHELL

*Our cover picture, taken in
British Guiana, shows a herd of
beef cattle crossing the Rupununi
River at Dadanawa. In
British Guiana beef is raised
principally on the coastlands
and in the Rupununi savannahs
in the far interior. With good
management and mineral
supplements cattle can be
successfully raised on these
savannahs, of which there
are still 2,000 square miles
unoccupied.*

Photo : C.O.I., London.

Soil Exhaustion in Tree Nurseries

by **C. A. R. Meijneke**

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1. *The poor growth in patches of this crop*
(Crataegus) *is a common symptom of*
'soil exhaustion' caused by nematodes.

Wherever tree cultivation is practised for many years on the same soil, certain difficulties are in time likely to be encountered. Crop growth deteriorates, and efforts at improvement by way of extra fertilisation, efficient tillage, drainage, and insect and fungus control are of no avail.

The grower, as a result of his failure, often decides temporarily to abandon his plots, and rents land elsewhere or exchanges plots with farmers in the neighbourhood. This usually involves extra expense and technical difficulties: cultivation is spread over scattered plots of ground, sometimes at a considerable distance from the nursery buildings; time and money are wasted in travelling from one plot to another; work is made more difficult, and often the results achieved on the new plots of ground are equally unsatisfactory.

After a time, the grower returns to his former plots, but he very oftens finds that the situation is unimproved in spite of agricultural crops having been cultivated in the meantime.

This poor growth which occurs after repeated cultivation of one crop is encountered in many tree nurseries throughout the world, and countries in which it is known include the Netherlands, Britain, Belgium, Germany, Scandinavian countries and the U.S.A. This phenomenon is known as 'soil exhaustion'.

Symptoms

A frequent symptom of soil exhaustion is poor growth of crops in patches (photograph 1). These patches are often oval in shape, with the largest dimension in the direction of the tillage; they may vary widely in size. The growth over the entire plot may also be poor or moderate, though this is sometimes difficult to confirm owing to the absence of a standard for comparison.

If some plants are dug out of one of these patches of poor growth, and some from the surrounding healthy crop, apart from a striking contrast in the development of the parts above the ground, a difference can also be seen in the root systems (photograph 2). Where the plant normally has a main root, this is usually absent from the plants dug out of the affected patches; a thick cluster of fine roots grows close to the root neck (photograph 3, left); the tips of many roots have died, and above this point new lateral roots have developed. The entire root system, therefore, has a 'bushy' appearance. Further examination reveals small brown patches on many of the roots. The entire picture is so typical that it is nearly impossible to mistake the symptoms. If the plant normally has no main root, the bushy appearance of the root system, the numerous brown patches on the roots and the dead roots (or parts of roots) are still apparent. These symptoms are not, of course, found in the plants from the parts of the plot where growth is normal.

Cause

Investigation in the Netherlands and elsewhere has established that the so-called soil exhaustion phenomena can in many cases be ascribed to various types of root nematodes living in and on the roots of the plants. This was established by investigation of root and soil samples from healthy and unhealthy patches (Table I), by inoculation tests (OOSTENBRINK, 1955) and by soil disinfection tests (MEIJNEKE, 1955).

2. Note the difference between the roots of a normal apple seedling (right) and those of a seedling from a 'poor growth' soil patch.

3. Seedlings of Prunus avium: *in those on the left the root system has a bushy appearance, the poor growth being in this instance due to attack by a nematode of the species* Pratylenchus. *The seedlings on the right have been grown in an unsuitable soil.*

In soil samples similar correlations were found. Very often a good correlation exists between the number of these nematodes in roots or soil and the growth of the plants (Table II).

Table II

Growth of the Test Crop (Strawberries) With a Decreasing Number of Nematodes (*Pratylenchus* sp.)

Object	1	2	3	4	5
No. of *Pratylenchus* sp. in 100 ml. soil ..	260	180	140	50	0
Total growth figures on 3 plots	18	20	22	25	27

Pratylenchus penetrans (Cobb) Sher & Allen was found to be the principal harmful species in tree nursery crops. Of course, poor growth, whether in patches or on entire plots, can also result from other causes. Naturally, soil fertility, the characteristics of the soil profile, water supply, etc. all play a part. In certain cases in Germany it has been found that a lack of trace elements, such as boron, can give rise to unsatisfactory growth. A case occurred in the Netherlands where the characteristics of the soil profile were the cause of poor growth in patches (photograph 3). In some cases, a previous crop may have left behind toxins or fungi in the soil, which have an adverse effect on following crops.

A case of the effect of a toxin on peach has been investigated in Canada (PATRICK, 1955), and one of the effects of fungi came to light on investigation in the Netherlands, where growth difficulties in the cultivation of *Rosa* seedlings could be overcome by application of a fungicide (not published). As a rule, however, these cases have been found

Table I

Investigation of Good and Bad Patches in Tree Nurseries.
Number of nematodes per 10 gm. roots in a number of crops.

Crop	Inside the bad patch			Outside the bad patch		
	P	O	S	P	O	S
I *Prunus insititia* L.	901	151	792	586	O	602
II *Crataegus* spp.	320	53	230	9	O	70
III *Prunus avium* L.	1,991	45	636	413	30	484
IV *Crataegus* sp.	2,600	50	1,060	211	O	68
V *Crataegus* sp.	5,080	330	2,420	288	90	122
VI *Crataegus* sp.	3,830	429	600	42	O	75
VII *Crataegus* sp.	1,070	x	x	140	x	x
VIII *Malus pumila* Mill.	295	x	x	5	x	x

P = *Pratylenchus* sp., mainly *P. penetrans;* O = other *Tylenchidae;* S = Saprozoic nematodes; x = not determined.

4. Seedlings of Rosa canina: *soil fumigation test. The plots in the foreground, left to right, were treated with EDB at 40 c.c. per sq. m., EDB at 80 c.c. per sq. m., and D-D at 80 c.c. per sq. m. In the second row the left-hand plot was untreated and the centre and right-hand plots were treated with chloropicrin at 80 c.c. and 40 c.c. per sq. m. respectively.*

in Holland to be much rarer than those of soil exhaustion caused by root-lesion nematodes, particularly *P. penetrans*. These nematodes attack a wide variety of crops and are very widespread and a number of agricultural crops (e.g. potatoes) are subject to damage by them. In a fairly limited number of cases this damage takes the form of a patchy but serious growth retardation, caused by dense local populations. In the majority of cases there is an even, relatively slight retardation of growth (and thus reduction of the harvested crop), caused by moderate populations of these nematodes. On the basis of numerous data, OOSTENBRINK (1956) estimates the general reduction in harvest caused by free-living root nematodes at 10-20 per cent.

Control

Since 1952, the Phytopathological Service in the Netherlands has been carrying out a series of tests to find out whether the destruction of *Pratylenchus* nematodes would end plant growth retardation. In pot tests, the nematodes were destroyed by the application of moderate heat (60°C) and steam (100°C). In field tests, specific nematocidal products, or products with a wider field of action (a dichloropropane-dichloropropene mixture [D-D], ethylene dibromide and chloropicrin; in a later stage also Nemagon, Vapam and various development products under the manufacturer's code number) were used.

In the field tests for tree nurseries soil fumigation always took place in the autumn on uncultivated soil ready for sowing or planting. In subsequent years, a tree crop was sown every spring (these included *Malus pumila*, *Prunus avium*, *Pyrus communis*, *Prunus malaheb*, *Laburnum anagyroides*, *Crataegus oxycantha*, and *Rosa* spp., etc.). The test fields were all arranged in plots heavily infested with *Pratylenchus penetrans*.

Several of the field-tested products were found to control *Pratylenchus* sp., etc. very well. D-D has so far been found to be one of the most effective and also one of the most economically justified of these products (BESEMER, 1955; BESEMER & OOSTENBRINK, 1957; MEIJNEKE, 1955 a and

b.) A dosage of 60 ml. per square metre[1] usually eliminates retardation of growth which has already occurred (MEIJNEKE, 1955 *a* and *b*); while a higher dosage, e.g. 80 ml. per square metre[2], usually has a much longer-lasting effect, due to the destruction of a higher percentage of nematodes. The results of such field tests can be seen both by the state of the crop (photograph 4), noted by growth evaluation numbers during the following season, and by the various grading data, such as thickness, height and percentage of saleable plants (photograph 5).

The cost of a D-D treatment at a dosage of 60 ml. per square metre in the Netherlands at present is Fl.1,400 (approximately £130) per ha. In many cases even the increase in returns of the third, and sometimes the fourth year crop after fumigation still exceeds the cost of treatment.

Table III

Increased Crop Value per Are (1/100 hectare) in Guilders After Soil Fumigation with D-D.

Test No.	1	2		3		4		5	
Crop after Fumigation	4th	4th		3rd		3rd		3rd	
Dosage ml. per sq. m.	60	80	40	80	40	120	60	120	60
CROP *Rosa canina*	11	27	17	139	85	31	12		
R. multiflora	29								
R. laxa	34								
Crataegus sp.								111	79

When assessing these figures it should be borne in mind that these results were obtained on test plots heavily infested with *P.penetrans* which had been carefully fumigated. As a rule, work in practice will be less thorough, and less striking differences, or shorter-lived effects, will be achieved. Very often, however, soil fumigation for these profitable annual crops will be a good financial proposition. In crops which are harvested only once in two or more years the cost of fumigation naturally weighs more heavily on the only crop achieved after fumigation and before the nematode population again reaches a high level.

Application of D-D

D-D is injected into the soil as a liquid at a depth of about 15 cm. (6 in.), and its action depends on the evaporation of this liquid and the penetration of the gas through the soil pores. It is therefore understandable that the action is

[1] 60 ml. per sq. m. = 2·0 fl. oz. per sq. yd.
[2] 80 ml. per sq. m. = 2·7 fl. oz. per sq. yd.
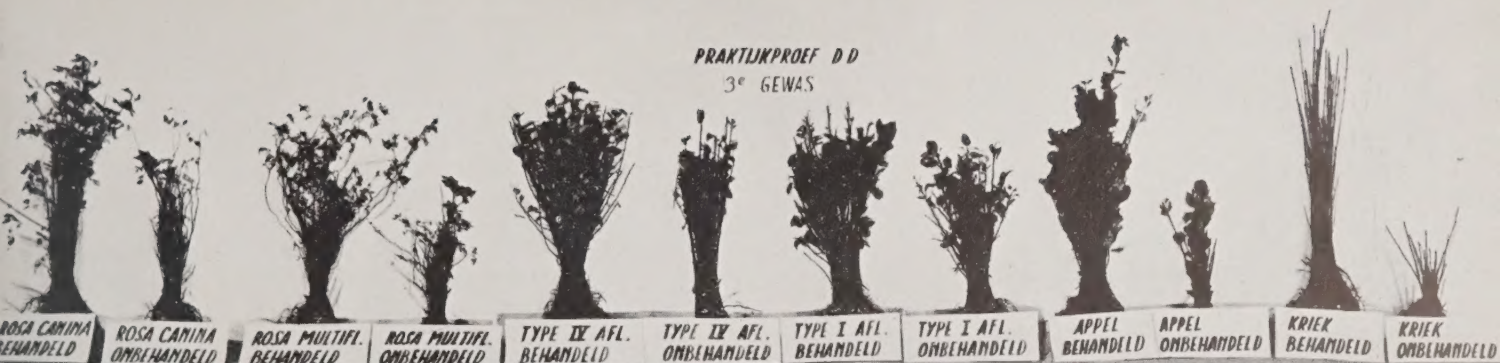
A number of seedlings (the left of each pair treated, the right untreated) demonstrating the effect of D-D at 60 c.c. per sq. m. From left to right the pairs of seedlings are Rosa canina, Rosa multiflora, *one-year-old rooted plants of the apple stocks* EM IV *and* EM I, Malus Pumila *and* Prunus avium.

dependent on the soil temperature of the upper layer of about 20 cm., the structure of the soil, and whether the pores are filled with water or not (D-D is not soluble in water). The higher the temperature at approximately 15 cm. depth, the more rapid the evaporation. At higher temperatures, however, (above 20°-25°C approx.) there is a risk of excessively rapid escape from the soil, so that the destruction of nematodes is inadequate. Its escape from the soil is, of course, also dependent on the humidity and structure of the soil: in dry light sandy soil the gas evaporates more quickly than from wet clay.

Where soil temperatures are high (e.g., in hot climates), the sealing of light soils with water after injecting the D-D may be recommended; it is sufficient for the top 1-2 cm. of the soil to be soaked and kept moist for a few days. Oiled paper can also be used for covering the soil. In temperate climates, as in the Netherlands, where soil temperatures usually are not very high, it is as a rule inadvisable to apply a water seal. This would cause the D-D to remain unnecessarily long in the soil, and the grower would have to wait an excessive time before sowing or planting, as D-D is phytotoxic (MEIJNEKE, 1955 *a* and *b*), and crops must not be planted while it remains in the soil. Rain shortly after disinfection has the same effect as a water seal. Soil temperatures below about 7°C are too low for fumigation with D-D as the product again remains too long in the soil.

When using D-D an important factor in the effect and in the prevention of phytotoxic action is the condition of the soil during and shortly after treatment. The best results are obtained when the soil is in seed bed condition: not too dry, not too wet, and in a loose tilth.

The nematocidal effect of D-D is usually completed in about one week; it is then important to get rid of the remainder of the D-D from the soil as rapidly as possible. For this purpose, the soil should be broken up several times (by rotary cultivator, fork or spade) so that the escape of D-D vapour is facilitated. If necessary, this should be repeated several times, at intervals of about a week. There should be no D-D remaining in the soil when sowing or planting is carried out (it is easy to tell by the odour whether there is still D-D vapour in the soil).

In good weather, and with proper after-treatment, in temperate climates the soil can be free of D-D in three to four weeks, so that sowing or planting can then take place. In unfavourable circumstances, particularly on very humus-rich moist soils, the product may remain in the ground for months and damage the crop. As a test crop, a few lettuces may be planted: they are highly sensitive to D-D and if they thrive all other crops can be planted.

Some remarks have already been made about the effect of the soil structure. Since the action of D-D depends on evaporation, it goes without saying that a friable or sandy, highly porous soil is more suitable for D-D fumigation than is a stiff, lumpy soil with few pores.

The composition of the soil is also of importance. Hitherto in the Netherlands little or no success has been achieved with D-D fumigation in heavy soils, probably due to insufficient penetration into the pores and on account of the compactness of this type of soil. Good results have been achieved on sandy, sandy clay and *dalgrond** soils. Even on the last-named soils, which are rich in humus, remarkable results have been obtained.

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* A *dalgrond* is the light soil which remains after the peat has been dug out of a peat soil.

The Importance of Trace Elements

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Although the terms "N", "P" and "K" have today become household words to farmers in many parts of the world, it is not yet so widely appreciated that these three elements constitute only a part—albeit an important one—of the concept of successful fertiliser practice. For optimum growth and yield plants require a variety of different chemical elements in greater or lesser quantities and it is the purpose of this article to outline briefly some of these lesser known, but very important, plant nutrients.

Throughout the ages the growth of plants has stimulated interest and controversy and it is therefore not surprising that we have today a detailed picture of the 'particular juyce' in the soil regarded by Sir Francis Bacon as the sustenance of plants. By 1855 it was known that plants required nitrogen, phosphorus and potassium for their growth, and the water culture experiments of Knop and other physiologists added the elements magnesium, carbon, calcium, sulphur, oxygen and hydrogen to this list. With the exception of hydrogen, oxygen and carbon, which the plants obtain from water and the air, these elements are absorbed from the soil, and have been designated the 'major elements' of plant nutrition.

When more detailed experimental techniques were developed it was found that healthy growth could not be maintained without the addition of further elements which were needed in far smaller quantities than the major elements. They were, therefore, called the 'micro', 'minor' or 'trace' elements. These elements are manganese, boron, copper, zinc and molybdenum. Iron occupies an intermediate position between the two groups but for the sake of convenience is usually classified with the minor elements. These, then, are the trace elements, and it cannot be too strongly stressed that for maximum crop yields they must be present in the soil in the correct proportions. If deficient, the crop yield is diminished, and if present in excessive quantities, toxic effects resulting in lower yields may occur. This toxicity is an interesting attribute of the trace elements and is a factor which must be taken into account when applying dressings of minor elements to remedy deficiencies.

The importance of this trace element balance between excess on the one hand and deficiency on the other is emphasised when it is realised that although their essential nature has long been recognised, vast areas throughout the world—notably in Africa, Australia, New Zealand and the United States—are still rendered unproductive by insufficient or toxic quantities in the soil.

A trace element deficiency may be due to several different causes. There may be a lack of a particular element in the soil which might be termed a 'true' deficiency, or the element may be combined with other minerals in such a way that the plant is unable to utilise it, giving rise to an 'apparent' deficiency. For example, the boron-containing mineral, tourmaline, is often found in soils on which plants exhibit boron deficiency. A further example is afforded by iron, which in neutral or alkaline soils forms insoluble compounds with the phosphates which can only be utilised slowly by plants. Thus the application of iron salts to the base of iron deficient citrus trees in California had little effect as the iron rapidly became 'unavailable'. Similarly, liming of certain soils has a depressing effect on the availability of copper, zinc, manganese and boron in addition to iron; but conversely it increases the free molybdenum content of the soil. It is possible, therefore, that injudicious liming to correct molybdenum deficiency may in turn induce a deficiency of a different element.

The examples described above refer to simple deficiencies: further complications arise when several elements are simultaneously deficient. Here visual diagnosis is of little value, the plant may show symptoms of several deficiencies, of one deficiency, or even none at all. It appears likely that the yields of many orchards in the United Kingdom are unnecessarily low because of a combined deficiency of several elements none of which is severe enough to cause visible symptoms.

However, formidable as these difficulties appear, once the deficiency limiting yield has been determined it is usually a relatively easy matter to prevent its recurrence by the adjustment of the soil pH or by the application of the missing nutrient to the crop in the form of a solid compound or as a foliar spray. In the case of fruit trees it is often more convenient to supply the required element in the form of a spray or as a pellet inserted under the bark of the tree.

Let us now look briefly at the salient features of the various minor elements.

Boron

Boron deficiency is found on light sands and gravels under conditions of high rainfall, and is more apparent in dry summers in soils containing appreciable quantities of calcium carbonate. It is commonly induced by overliming, and on soils likely to be low in boron it is advisable to use the water-soluble boron content of the soil as a guide to liming levels. The amount needed by plants for optimum growth is relatively low and the range between deficiency and toxicity is narrow. For many plants a concentration below 0.01 p.p.m. will produce deficiency symptoms, whilst a concentration of 1 p.p.m. is likely to be toxic to boron-sensitive crops.

Boron deficiency is most marked in root crops, but also produces recognisable symptoms in other crop plants and fruit. In all cases it causes considerable distortion of the leaves and the death of the apical growing point. It is this characteristic which has given rise to the diseases known as 'heart rot' of sugar beet and 'brown heart' of swedes and turnips. Treatment can be effected by soil applications, foliar sprays or stem injections of borax.

Boron toxicity is best corrected by providing adequate drainage in the affected areas, as boron is readily leached from the soil.

Copper

Soils high in organic matter and weathered sandy soils are likely to be deficient in copper. A serious deficiency may cause stunting of growth and visible symptoms of disease in plants, but moderate deficiency may merely depress yields.

Deficiency symptoms vary considerably and no general description can be given. Citrus is particularly susceptible, copper deficiency giving rise to the condition known as 'exanthema' or 'dieback'. This disease is particularly prevalent in the United States and is characterised by stained fruit and bark and by multiple bud formation.

A condition known as 'reclamation' disease or 'yellow

Marrow stem kale exhibiting symptoms of manganese toxicity. Note the cupping of the leaves and the necrotic spots towards the leaf edges.
Photo: Plant & Soil

An apple tree in which copper deficiency has resulted in die-back of the bark and ultimate death of the tree.
Photo: University of Bristol

Zinc deficiency has caused rosetting of the leaves of this apple tree.
Photo: University of Bristol

tip' responding to copper fertilisation has been described in grain crops in several parts of the world. Here, diagnostic features include dwarfed and distorted heads, marginal chlorosis of young leaves and necrosis of the tips of older leaves. Treatment depends largely on the crop, the severity of the deficiency and the pH of the soil, but is normally effected by the use of copper sulphate as a soil dressing—or better still as a spray.

Zinc

A variety of soils may be zinc-deficient but this deficiency is most common on neutral or alkaline sands. It occurs extensively throughout the United States and Australia, and has been reported under field conditions in at least 20 different countries. As in the case of both boron and copper, liming is said to induce the deficiency and, in addition, zinc deficiency is accentuated by heavy applications of phosphatic fertilisers.

Zinc deficiencies are spectacular in nature because of the combinations of chlorosis, rosetting, dieback and depressed growth which may occur: deciduous fruit trees are especially sensitive; the leaves are dwarfed and mottled in appearance and the failure of terminal buds to elongate gives rise to the condition known as 'rosetting'. As the disease increases in severity branches may die back, and since the condition is affected by light intensity the trees may present a lop-sided appearance. The disease is also widespread in citrus growing areas, symptoms being somewhat similar to those described above.

Where the deficiency has been proved, remedial action may be taken using zinc suphate either as a soil dressing or as a spray. On alkaline soils rich in organic matter the former method is largely ineffective and a foliar spray is more economical. However it now seems likely that the recent development of chelated zinc compounds will vastly improve zinc fertilisation practice.

Zinc is far less toxic than either boron or copper but can be controlled by liming the soil up to pH 6-7.

Molybdenum

Although the distribution of molybdenum in the soil is very extensive, molybdenum deficiency is a more or less typical symptom of acid soils, because molybdenum is one of the few elements that become relatively less available as soils become more acid. Where the disease is a 'true', as opposed to an 'induced' or 'apparent' deficiency, remedial applications are very low. Unfortunately this has led many farmers in New Zealand to overdose with molybdenum, since they cannot believe such small doses to be effective. This has caused many cases of molybdenum toxicity in cattle and sheep. Because of this it has been suggested in New Zealand that vanadium might be substituted for molybdenum in fertilising pasture crops since vanadium seems to perform the same functions as molybdenum and is at the same time far less toxic to cattle.

Deficiency symptoms have been described in a number of crops and well known diseases such as 'whiptail' and 'yellow spot' are both caused by a lack of this element.

The deficiency can often be cured or alleviated by liming,

and phosphatic fertilisers are also described as increasing the molybdenum uptake by crops. Molybdenum has been satisfactorily incorporated into superphosphate and this is reported as having given good results on molybdenum-deficient pastures.

Manganese

Extensive manganese-deficient areas exist in the United States and the deficiency has also been recognised in many parts of Europe and Africa, and in Australia and New Zealand. It is found, in particular, on light alkaline soils rich in humus. The pH of the soil seems to have a profound effect on the availability of manganese to plants and it is probable that many soils reported as manganese-deficient have, in reality, adequate manganese but in such a form that it cannot be utilised by plants. It has been shown that soils with a pH above 6.0 favour the oxidation of manganous compounds—a form of manganese readily utilised by plants—to manganic compounds in which the manganese is unavailable. Hence, as with copper, boron and zinc, great care must be taken when applying lime to acid soils as injudicious liming may induce manganese deficiency.

The deficiency is characterised by a marked chlorosis of the leaves and may ultimately cause the death of the plant. Typical examples of diseases caused by manganese deficiency are the 'grey speck' disease of oats and the condition known as 'speckled yellows' in beets.

Corrective treatment consists of the application of manganese sulphate either as a soil dressing or as a spray.

Iron

Like manganese, iron deficiency is usually induced, liming being an especially common cause. It is found in many fruit growing areas of the United States and in many tropical soils. Crops affected are markedly chlorotic and occasional leaves are completedly bleached; the visual symptoms are often indistinguishable from those produced by an absence of manganese and are not always of diagnostic value. Fruit is especially sensitive and should on no account be grown on soil which is likely to be deficient in iron. Cereals, on the other hand, are extremely resistant and are eminently suitable for growing on iron-deficient soils.

Treatment is rarely a simple matter. If directly applied to the soil iron salts are quickly lost to the plant, especially on alkaline soils. Nor is foliar spraying always efficacious as leaf scorch may result from spraying, and stem injections, although often successful, are extremely tedious. The recent discovery and subsequent development of iron chelates has, however, enabled chlorotic conditions in fruit trees to be controlled within five to eight weeks.

It is evident that the pressing need for increasing the world's food supply in the face of the growing population makes the problem of trace element deficiencies of prime importance. Vast areas throughout the world are producing greatly reduced yields, which, it must be stressed, are not greatly increased by the application of the 'major' nutrients alone. Only with a completely balanced fertiliser programme can maximum yields be obtained.

SOME PRINCIPLES OF SELECTIVE WEED CONTROL

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Improved methods of weed control have undoubtedly played an important part in raising crop yields in many countries over the past few decades. This has been largely achieved by the use of chemical weedkillers which possess 'selective' action. Ideally, such substances have the property of singling out the weed for destruction, leaving the useful plants unharmed, and in practice they do destroy many kinds of weeds with little crop damage. The success of such an operation, however, may depend a good deal upon rainfall, temperature and other climatic factors as well as on soil type and situation. It is therefore not always possible to achieve spectacular, or even satisfactory, weed control because of factors which are not related to the chemical concerned.

Farmers these days have become so used to expecting new scientific developments to aid their farming operations that they have ceased to wonder at the truly remarkable way in which science is helping them on their own farms. The use of selective weedkillers provides a good illustration of this point. After all, why should a chemical, when applied to a mixed population of plants, kill some and not others? It is true that a crop plant and a weed may differ in size and shape, but their basic make-up cannot be greatly different for both are living in the same way, taking water and food material through their roots from the soil and sunlight and carbon dioxide through their leaves. How, then, do we ever manage to effect weed destruction in the presence of growing crops, and what are the important principles involved?

The first thing to note is that no chemical can be expected to kill all weeds growing on the cropped land nor, in practice, is it always necessary to kill a weed outright with the chemical, for as the crop develops, its smothering action on the affected weeds will either finish them off or keep them small, so that their effect on the growth of the crop is negligible. When the dominant weeds in a crop are markedly different from the crop itself, the chances of selective weed control are usually much better than when weed and crop belong to the same family. Thus, for example, the chances of finding a weedkiller to destroy wild oats in an oat crop are small, whereas charlock, as everyone knows, can readily be dealt with in a field of wheat.

All progressive farmers realise that chemical weedkillers are no substitute for good farming. Good farm management, however, with proper crop rotations in conjunction with chemical weed control where it is needed can keep the land clean with the most economical use of labour. It is obvious from what has been said already that a thin, poorly growing crop will not provide the competition necessary to prevent the recovery of weeds which have been checked and not killed by spraying; for such reasons it is quite easy to see why identical spraying operations may be completely successful on a well managed farm and not on another.

Basic Problems

Now let us turn to a consideration of the basic problems of selective weed control. Chemists and biologists are working strongly together in this field and although the search for new weedkillers is still in many ways a very empirical procedure, certain principles are emerging from these studies which are enabling research workers in this field to adopt a more logical and scientific approach.

As has been pointed out above, while all plants are similar with regard to their physiology, nutrition, etc., different species can show marked differences in structure and habit of growth. It is on such differences that the first principle underlying selective herbicidal action operates. If we take a cereal plant, for example, we have tall erect waxy leaves and a protected growing point—in fact quite a different structure to that of many weeds which have flat horizontal leaves with the growing point exposed. When a spray containing, say, sulphuric acid is applied, the cereals

suffer little damage because the spray droplets tend to roll off the waxy leaves. Broad-leaved weeds, however, are severely affected because their leaves retain the spray; furthermore, the growing point is exposed to the action of the chemical. In this way a kill of many broad-leaved weeds in cereal crops may be achieved with a number of chemicals, including copper salts and dinitro compounds such as DNOC (dinitro-ortho-cresol).

The type of waxy covering on the leaves and stems of the plant can also influence herbicidal activity in other ways, for even if the spray is retained, the chemical still has to pass through the cuticle before it can enter the tissues. Much is now known about the factors which are of importance in regard to the penetration of herbicides through this cuticular layer. Once inside the plant, some herbicides produce sudden and lethal effects on the cells; others move in the tissues and exert a toxic action which is more prolonged. Basic studies on the translocation of chemicals in plants, and the chemical changes which might occur within the cells, have helped to provide some understanding of the mode of action of a number of the herbicides in present-day use.

Pre-emergence Treatment

A second type of selectivity can operate when the chemical is applied just before the crop seedlings have broken through the soil. Examples of this type of 'pre-emergence' treatment are provided by the use of sulphuric acid for direct seeded onions and pentachlorophenol for sugar beet and other root crops. The aim is to destroy the small weeds which have emerged at the time of treatment, and the selectivity depends upon a physical protection provided for the crop seedlings by the thin layer of soil above them. For the crop to remain unharmed, it must either be tolerant of the chemical at the seedling stage or the substance must have disappeared from the soil or have been rendered non-toxic by the time the crop emerges.

In some cases, a herbicide is applied to the soil before the crop is sown, as, for example, in the control of wild oats in sugar beet, where trichloroacetic acid is applied before the final seedbed cultivations. Here the aim is to ensure that the chemical is there when the wild oat seed germinates. It is not known why the weed happens to be very susceptible to the action of the herbicide at this stage, whereas sugar beet is not. The use of most of our present-day herbicides is in fact based on empirical discoveries of this sort. Dinoseb (dinitro-sec-butylphenol), for example, applied at rates of 1-2 lb. per acre as a high volume spray, has been found to give an effective control of many weeds without causing serious damage to peas, though weather conditions may seriously affect the degree of weed control obtained.

The selective action of dinoseb may be dependent to some extent on the fact that peas have a waxy cuticle which prevents the plants from becoming well wetted by the spray. If this were the main reason for selectivity, however, the cheaper and equally herbicidal compound, DNOC, should be just as selective. In fact, DNOC is too damaging to be used on this crop.

As with many other weedkillers, it is not known precisely how dinoseb, DNOC and similar dinitro derivatives exert their herbicidal action. Most of these compounds, as already indicated, were discovered by the routine testing of a large number of unrelated chemicals. The success of a herbicide in the field, however, usually leads to studies on its mode of action and such investigations can be of great value in the search for new effective compounds.

It has recently been reported that herbicides derived from N-phenylcarbamate, such as propham and chlorpropham and the compounds monuron and aminotriazole act by interfering with one of the important reactions concerned in photosynthesis; whilst dalapon, a translocated weedkiller which is very specific in its action on grassy weeds, is thought to act by preventing the formation by the plant of an essential substance, pantothenic acid, which is one of the B vitamins.

It is obvious that with the extremely complex biochemical systems operating in plants there must be hundreds of ways in which a chemical can prove toxic, once it has penetrated into the cells. It is not surprising, therefore, that as yet we have only a very limited knowledge of how herbicides exert their toxic action at cell level. This, indeed, applies with the most important group of all—the 'hormone' herbicides, which are plant growth regulators typified by 2,4-D (2, 4-dichlorophenoxyacetic acid) and MCPA (2-methyl-4-chlorophenoxyacetic acid). As is well known, such compounds are able to promote growth responses in many species of plants when applied in concentrations of only a few parts in a million of water. Some of these effects are important commercially; growth substances are used, for example, to promote rooting in cuttings, for preventing pre-harvest drop of apples and for inducing tomato flowers to 'set' in the absence of pollination. When used at higher strengths, however, say up to 0.1 per cent., the effects on the plant can be very drastic indeed; twisting and distortion may occur with splitting of the stem, and destruction of the growing point. Although such plants cannot survive, it may be some time before they die.

Systemic Action

An interesting property of the hormone herbicides is that they can apparently be absorbed by leaves, stems or roots and, once they have entered the plant, they can move and so become distributed through the tissues. However, different species of plants do not all show the same degree of susceptibility to the hormone herbicides: cereals and grasses, for example, are more resistant than other plants, so that by choosing the right dosage rates—usually about 1 lb. per acre—it is possible to use MCPA and 2,4-D for controlling certain weeds in these crops.

The widespread use of these compounds for destroying weeds in cereal crops has resulted in large increases in yields as well as a great saving in farm labour. Their value was brought out in spectacular fashion in a recent American Congressional report which stated that the work of one man in a chemical plant producing 2,4-D equals the toil of 800 farm workers. Although such a statement will not bear analysis it does emphasise the tremendous impact

Wheat cylinder test : segments of wheat stem tissue elongate only slightly in water but to an increased extent in a solution of a growth substance.

Before treatment.   After 24hr treatment

WATER CONTROL   1ppm 2/4 D ACETIC
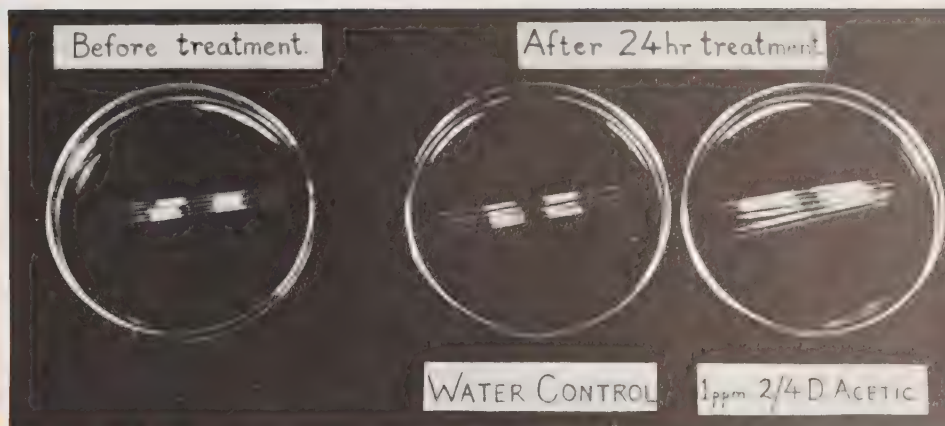
Pea curvature test : segments of pea stem split for two-thirds of their length bend outwards in water but inwards in a solution of a growth substance.

After 24hr. treatment

WATER CONTROL   1ppm. 2/4 D. ACETIC.

These pea seedlings received an application of MCPB at 1/3 gal. per acre three days before the photograph was taken. The seedlings are undamaged, but already there is some sign of distortion in the weeds.

which these herbicides have made upon agriculture. Not only are the compounds destructive to many weeds but they have the advantages that they can be sprayed in water solution, are not poisonous and are not expensive.

In studying the mode of action of the hormone compounds, their activity and that of closely similar chemicals has been assessed not only in weed control experiments but in sensitive growth tests, some of which, such as the wheat cylinder elongation test and the pea curvature test, are carried out in the laboratory, under controlled conditions, on segments of plant tissue (see illustrations). As a result, we now know much about the features of the molecule which are important in relation to its movement within the plant and to its behaviour when it reaches the site of action within the cells. But nothing really is known yet about this site of action, nor how the chemical, when it reaches there, induces growth responses in the plant.

The Butyric Herbicides

There have been two interesting developments in the hormone herbicide field during the past few years, and both have arisen in Britain. The first, which originated in the writer's laboratory (6), came unexpectedly from a biochemical investigation on the oxidation of certain fatty acid derivatives within plant tissues. During this work it was shown that the mechanism of this oxidative breakdown of fatty acids is similar to that known to take place in the animal body. Such considerations led to the preparation of a number of chemicals which are related both to powerful herbicides like MCPA and to the fatty acids. These chemicals, whilst harmless to plants in themselves, were nevertheless found to be systemic, entering through the leaves or root system and moving in the tissues. Strong evidence was obtained, however, that once within the plant cells, certain of these harmless chemicals could be slowly converted to a powerful herbicide, in which case the plant was eventually destroyed.

Of the range of chemicals studied, two were selected for more intensive investigation, namely MCPB (γ-[2-methyl-4-chlorophenoxy] butyric acid) and 2,4-DB (γ-[2,4-dichloro-phenoxy] butyric acid). Both of these compounds appeared to be broken down readily in the cells of certain plants, but not in others. For this and other reasons they were selective weedkillers, killing only those weeds and crops which had the capacity to absorb them and break them down in their tissues to release the toxic chemical. The results of many glasshouse and field experiments indicated that a number of important legume crops, such as clover, lucerne and peas, cannot readily effect this vital conversion and these 'butyrics' are now proving useful and very specific herbicides in such crops.

The use of MCPB and 2,4-DB, then, illustrates a new principle of selectivity which depends primarily upon basic differences in chemical activity of susceptible and non-susceptible plants. The compounds are now finding use in many countries for the control of weeds in legumes and undersown corn crops (3).

The other recent development in the hormone herbicidal field was the discovery by Lush (5) and Leafe (4), of Boots Pure Drug Company, that MCPP (α-[2-methyl-4-chloro-phenoxy] propionic acid), a near relative of MCPA, whilst possessing most of the selective weedkilling properties of this substance, is less toxic to cereals and also gives an effective control of cleavers (*Galium aparine*) and several other weeds which are resistant to MCPA and 2,4-D. This discovery was of great importance to the farmer and the compound was used extensively last season in the U.K., particularly in cereals where cleavers were a problem.

Herbicidal Activity

The case of MCPP provides a good example of how the growth-regulating properties of a substance, assessed in the laboratory, can indicate herbicidal activity. This compound was in fact one of the most highly active of all those examined at Wye (1 & 2) in two separate investigations in 1953 and 1955. It was shown to possess similar activity as a growth substance to MCPA and it was concluded that the basic activity of these compounds is probably the same. Why, then, should MCPP effectively control cleavers while MCPA does not? The answer to this question cannot yet be given, but the difference is unlikely to be concerned with mode of action at cell level. It is probably related to differences in chemical stability within plant tissues, or to the slightly different physical properties of the MCPP molecule, which enable it to penetrate into and move within the cleaver plant better than can MCPA.

This important indication that slight changes in the molecule of active chemicals can alter their weedkilling spectrum may well lead to further interesting developments in the future. Already most striking results are being obtained in this direction. In one case recently discovered at Wye, slight changes in the molecule of a chemical, active as a pre-emergent herbicide, reversed its selectivity completely.

As more attention is given to fundamental studies on herbicides, so more will become known on the problems of how such chemicals exert their toxic effects. Already, as has been indicated, there are some well defined principles underlying selectivity.

In spite of its world-wide importance, chemical weed control has, for some reason, not attracted the attention of scientists in the past to the same extent as have the related studies of pest and disease control. The situation, however, is rapidly changing, and physical, organic and bio-chemists are now joining with the plant physiologist and ecologist in making fundamental studies of the chemical destruction of weeds in crops. Such investigations must certainly lead to important and impressive developments in the future.

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Reducing Drift from Ground Sprayers

by **R. J. Courshee,** *National Institute of Agricultural Engineering (U.K.).*

For damage to occur on down wind crops when spraying a herbicide, three things must happen: first, there must be drift, and secondly it must be transported from where it arises to the areas where it can cause damage. Thirdly, the down wind crop must be inherently sensitive to the herbicide; it must be at a development stage and in a growing state when damage can occur, and it must also be exposed to the drift, receive it and absorb it.

So we see that damage is a subject of many facets, and each factor can have a powerful bearing on the end point—damage. If we could break the chain of cause and effect at any point, then the damage could be prevented. This we have been trying to do at the National Institute of Agricultural Engineering by reducing the amount of drift occurring at the source—i.e. the sprayer. While it is of value, this is a limited approach in that reducing the drift merely reduces the chances of drift damage; it tells us very little about how much damage is still likely or where it will occur. This depends upon the other factors involved.

As an example, the complexity of studying the transport of the drift from one field to another can be described in order to justify the restriction of the N.I.A.E.'s work to only one factor, namely preventing the drift from arising.

Transport of Drift

The conventional plant protection textbook information on the transport of small drops in the atmosphere usually describes the trajectory of the spray drops as a line determined by the wind speed and the terminal velocity of the drops. This is a valid description of the phenomenon of the movement of drift when it is composed of heavy drops—say 500 microns in diameter.

Spray drift from ground crop spraying, though, contains only drops smaller than about 150 microns (depending upon the wind speed), and in this case this simple theory no longer holds good. In fact 150-micron drops spread in much the same way as a smoke does, some going up, some landing 5 yd. down wind and others still airborne at a range of 100 yd. or more, depending upon how stable the atmosphere is. If the drops are of water they may evaporate quickly, and starting off as 150-micron drops become 30-micron drops of concentrated solution before they land, and accordingly pursue a different path. Finally the density and height of the crop in the field being sprayed, and in the down wind fields, will affect the capture of the drift before it reaches the sensitive crop.

These are factors to be considered for a more complete study of the elementary theory when drift moves over a horizontal and uniform surface. The subject is very much less clearly understood when drift moves over undulating terrain and around or over obstacles like hedges and houses, and most particularly when the drift moves towards a glasshouse.

Because of the probable complexity of tracing the path of the drift we can more economically pursue the narrower aim of preventing drift from starting. Even then we shall still not have any idea of what drift is likely to cause harm. But we shall be able to say, for example, that by using the machine in a particular way, the amount of drift is reduced to half its usual value. Then we might make a guess that the aggregate amount of damage which is likely to arise

will, other things being equal, also be reduced by a half. That is, the damage may occur once when it might previously have occurred twice or it may be half as severe or it may extend half as far. There will at any rate be an improvement.

Occurrence of Drift

In a spray there are always small drops amongst the big ones. If a wind blows past the spray sheet these small drops may be seized by it and become drift. So there must be small drops and a wind to take them away for drift to occur. The higher the wind speed the bigger are the drops forming the drift and the more there are of them.

The spray must be exposed to the natural wind or to the wind which is caused to blow past the spray by the motion of the tractor. As the spray itself also causes an air stream to flow with it and carry the small drops downwards, a nozzle with a greater output might permit less interference by the wind, before the spray is down to the level of the vegetation where, provided there is a sufficient crop surface to impact upon, the fine spray might be trapped. So crop density will certainly play a part and nozzle throughput might do so.

The several factors involved all interact: higher pressure might permit the spray to penetrate the crop more surely, but higher pressures also give rise to more small drops, which are likely to drift, than occur at lower pressures. Larger capacity nozzles in general give a smaller fraction of their spray as small drops and the greater momentum of the spray from the larger volume emitted also gives these few small drops a better chance to reach the vegetation.

So a number of moves might be made to reduce the drift occurring. Sometimes an improvement in one direction results in a step backwards in another. The results presented below are still only approximate and no account is taken at this stage of the interactions between individual factors, nor are all the factors considered. Nevertheless some figures which will serve as a guide are given and used to justify tentative recommendations for the setting of ground sprayers for applying hormone type weedkillers.

Below are outlined some possible steps to minimize drift.

Occurrence of Small Drops

Pressure. If the spray pressure is increased then a larger fraction of the spray becomes small drops. This is illustrated for a particular nozzle, nozzle *A*, in Fig. 1, where the fractions of spray as drops smaller than 125 microns is 3 per cent. at 15 p.s.i., 9 per cent. at 25 p.s.i. and 11 per cent. at 35 p.s.i. Therefore if it were not for the fact that the higher pressure is a little more effective in getting the spray down into the crop, we might expect drift from this nozzle at various pressures to be in the same ratios— 3 : 9 : 11. In practice, the drift at these three pressures was found to be in the ratios 3 : 4 : 5. So the large increase in the fraction of the spray present as small drops is not translated completely into a corresponding increase in the quantity of drift. Nevertheless, the pressures should be kept low, to, say, 15 p.s.i.

Nozzle throughput. Small drops form a larger fraction of the spray from small nozzles than they do from large nozzles. Therefore large nozzles should give rise to less drift than small nozzles.

If, for example, in a series of similar nozzles, nozzle *B* (delivering 5 gal. per acre) is compared with nozzle *C* delivering 17 g.p.a., both at 35 p.s.i., we find, as shown in Fig. 2, that the fraction of the spray which drifts is nearly half as much for the larger volume application. The change from 5 gal. to 17 gal. per acre is accompanied by a corresponding reduction in concentration of the spray, so that the amount of herbicide applied per acre remains the same. Thus the reduction of the fraction of the spray as drift to a half results in half as much herbicide drifting from the large volume application, even though the volume of water in the drift is greater. Of course this improvement pertains to these particular nozzles and to a particular wind speed— here, 10 ft. per sec. For other pairs of nozzles, other pressures or other wind speeds, the improvement resulting from increasing the number of gallons per acre applied from five to 17 might be smaller or larger than the particular 50 per cent. improvement obtained in this example.

Thus a second recommendation might be that it is valuable to avoid applying very small volumes per acre, mainly because smaller volumes lead to more small drops on conventional sprayers. But spray volume is really a quite separate factor from spray drop size and there is no obstacle at all to applying small volumes in the form of large drops if a machine is designed to do the job. For conventional machines, however, the larger the volume the less the drift—but the improvement obtained for the inconvenience is a small one and it seems that 10 gal. per acre provides a good compromise point between reduction of the burden of carting water and the prevention of drift.

Nozzle design. No clear cut evidence is available to indicate whether different classes of standard nozzles applying the same volume per acre give different numbers of small spray drops.

In general, a roughly made nozzle will give a wider spray spectrum, ranging from very fine to very coarse drops, while a smoother nozzle would not give so many coarse drops. But we still cannot suggest that any one type of nozzle will give rise to fewer small drops per volume applied than an alternative type working under the same conditions. However, without producing evidence, we can say that flat sprays will probably give rise to less drift than cone sprays when both of them have a similar content of small drops. This is because a cone nozzle is fully exposed to the wind from whichever direction it comes. A flat nozzle, on the other hand, is exposed mainly only to the wind in the direction the tractor is moving. A wind parallel to the boom of the sprayer strikes only the narrow edges of the flat spray sheet and may not be able to winnow out the small drops completely.

One other advantage of flat nozzles, from the particular view point of preventing drift, is that they can be inclined backward from the boom so that this in turn may be lowered. The difficulty of maintaining the boom height accurately precludes putting it closer to the crop than about 12 in. Nevertheless, 12 in. gives less drift than 18 in. but

Spray Drift : *the left-hand picture shows how a spray cone can be deflected by mud. In the right-hand picture drift is being prevented by the use of a light-weight flexible deflector.*

FIG. 1

FRACTION OF SPRAY PRESENT AS SMALL DROPS

PRESSURE	15	25	35 LB./SQ. IN.

SMALL DROP SIZE FRACTION
OF SPRAY VOLUME

3%	9%	11%

FIG. 2

DRIFT FROM SMALL VOLUME 5 G.P.A. AND MEDIUM VOLUME 17 G.P.A SPRAYING

AT 35 P.S.I.   VOLUME APPLIED   5 G.P.A.   17 G.P.A.

PER CENT. OF SPRAY AS DRIFT   28·6%   15·4%

FIG. 3

DRIFT FROM NOZZLE A AT DIFFERENT WIND SPEEDS

PER CENT. OF SPRAY AS DRIFT   2·3%   10·5%   14·4%

WIND SPEED   5 FT./SEC.   10 FT./SEC.   15 FT./SEC.
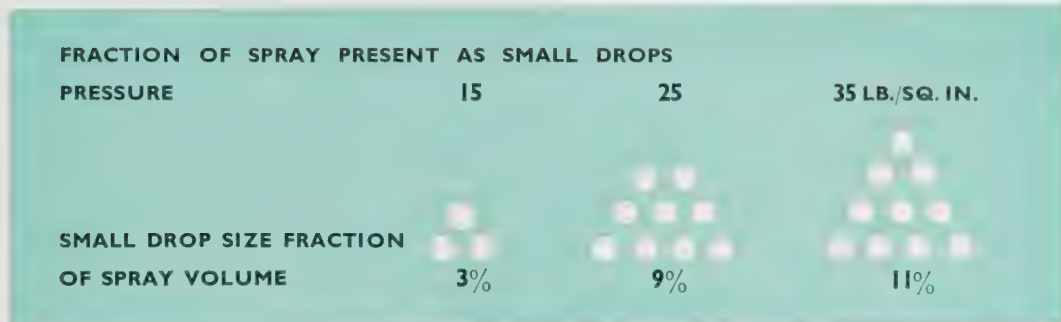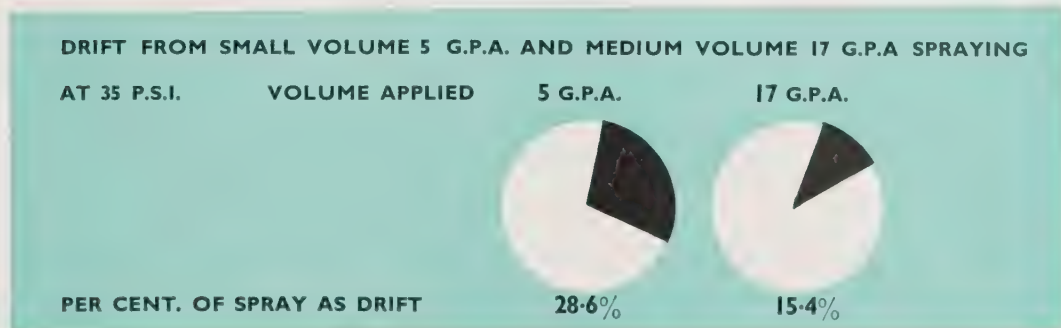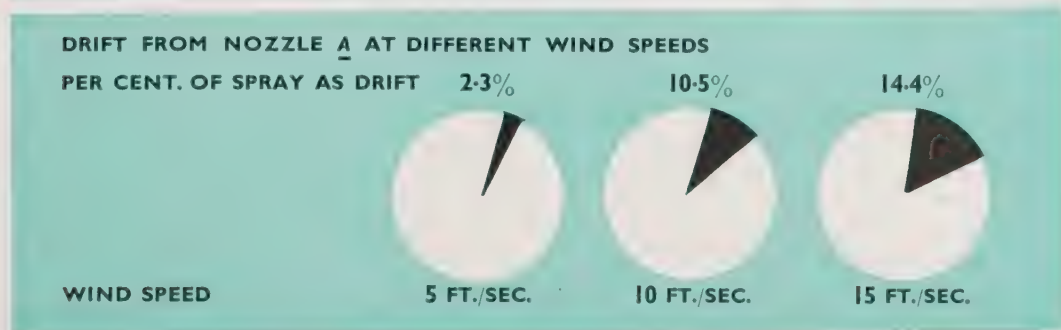
of course the flat nozzles must then be tilted backward at an angle of 45° to avoid the streaky deposit which would otherwise arise from 60° spray angles. In this type of application a deflector to drive the spray down must be used; if it is omitted more drift will occur, and not less, as soon as the nozzles are inclined backward.

Effect of Wind

The drift increases rapidly with wind speed as bigger drops are carried off, as shown in Fig. 3; so, in general, avoiding a wind reduces damage. But this over-simplifies the picture and it fails to explain the notorious cases of damage occurring when a spray operator has conscientiously waited for nearly calm conditions.

Since the sprayer is moving at 4 m.p.h. or more, the nozzle is in effect always in an air stream, and the fine drops are winnowed out into a cloud behind the spray. If there is a slight natural breeze also, as there nearly always is, even of only 1 m.p.h., much of the drift will be carried down wind. Most importantly for most of the drop sizes which form the drift, a slight wind is as able as a 6 m.p.h. breeze to carry the drift away.

In a 6 m.p.h. breeze, though, the drift is quickly scattered and diluted, with much of it being deposited in the field being sprayed, so that the contamination of susceptible down wind crops may be quite slight.

If, on the other hand, there is very little wind and, as then often happens, the atmosphere is very stable, the drift which has arisen through the motion of the sprayer is now not diluted by the wind. The cloud may move slowly but steadily, with very few losses *en route*, and will also remain more concentrated and dangerous than it would in a fresh breeze.

Dilution of the drift cloud in a breeze might be a very necessary safety factor to avoid drift damage. This would be particularly true of aeroplane spraying where the very high forward speed gives rise to a large amount of drift—much more than would be caused by a normal wind.

In all, the density of contamination of susceptible crops down wind might occasionally be greater if there were only a little wind than it would be if a fresh breeze scattered the cloud over a wider area. But this depends upon all the factors which control the scatter of the drift.

We have, in a qualitative manner, arrived at one of the complex issues concerned with where the drift goes to after it has been formed. But it could not be avoided because, although a higher wind speed gives more drift it may not always give more drift damage, when the drift happens to be towards a susceptible crop, and it was necessary to consider the subject of the transport of drift to suggest the reason.

The one concrete piece of advice to come out of this is that although an increase in wind increases the chance of damage, usually it may also be dangerous to spray in a near calm, say with a wind speed of less than 2 m.p.h. So the standard recommendation to avoid spraying when there is a wind towards a susceptible crop in the next field should be extended: if there is an almost imperceptible and steady breeze, typical of stable air conditions, probably no damage

at all will occur, but there is some possibility of severe contamination even at a long range. Unfortunately we have no expectation of being able to measure the likelihood of damage under such conditions.

Clearly a boom cover which shrouds the whole spray prevents nearly all the fine spray from leaving the sprayed area; but the use of these boom covers is inconvenient and rarely justifiable (it is not necessary for present-day herbicides).

On the other hand, drift increases so much with an increase of wind speed that a simple and convenient device to reduce the wind speed partially might be of value. (This is the wind speed which causes the drift—not the wind speed which carries it away, which we have already noted is of little importance.)

If a deflector is placed behind the boom to drive the air carrying the drift towards the crop, about half of the drift which occurs with nozzle A at 15 p.s.i. can be prevented. Some of the drift actually lands on the deflector and drips off (a check may be needed to ensure that this does not matter). The remainder of the drift appears to the eye to be pressed down towards the crop and trapped more completely on it. At any rate, the use of a simple deflector will reduce the amount received on a target at a distance of two metres by half, but the result does depend upon the density of the crop.

Conclusions

As a result of the work which has been done so far, the following conclusions can be drawn. Drift can be reduced by about 90 per cent. from the level occurring with a 5 gal. per acre application at 35 p.s.i. with nozzles 18 in. from the ground; by using larger nozzles to apply 10 gal. per acre at 15 p.s.i.; by lowering them to 12 in. and using an 80° angle nozzle to replace the conventional 60° nozzle; and by fitting a deflector to drive the drift which still does occur down into the crop.

Some changes may thereby arise in the degree of selectivity of the spray or even in its effectiveness, but if they do, they will probably be so slight as to be of negligible importance.

The quantities of drift, then, reaching to a distance of 10 yd. down wind is of the order of 0.1 per cent. of the spray applied. Although about 1 per cent. of the spray volume becomes drift at a wind speed of 7 m.p.h., most of this quickly lands in the first few yards down wind with less than 0.1 per cent. actually leaving the field being sprayed. It is still enough to cause damage but probably only if some particular feature of the topography and of the wind pattern causes an unusual concentration of this tiny amount of drift on to a small area. That is why we probably do not need to study (nor can study economically) the transport of the drift down wind.

Damage is very unlikely to be caused by normal drift when the precautions suggested are used, and it would be very difficult to identify specific features of the landscape or the wind which might lead on rare occasions to abnormally dense deposition of the drift at particular places, and consequent damage there.

The Shell stand in the exhibition hall provided a convenient meeting place for delegates.

MALARIA SURVEILLANCE STRESSED AT LISBON CONFERENCE

The subject of malaria eradication gave rise to many stimulating and informative papers and discussions when the Sixth International Congress on Tropical Medicine and Malaria was held at Lisbon last September.

The Congress was concerned with every branch of tropical medicine—some idea of its scope may be gained from the fact that there were always four sessions proceeding at the same time—and the impressions recorded below refer only to those sections dealing with insect-borne diseases, and in particular with their control by insecticides.

The Congress brought together delegates with considerable knowledge of administrating and operating malaria eradication programmes, and the realistic tone of discussions reflected this experience. It is now becoming possible to forecast, with greater accuracy than hitherto, the time required to eradicate the disease in individual countries. In a number of countries it is proving necessary to extend the attack phase beyond the period originally planned.

The importance of efficient surveillance was stressed by several speakers; this is an operation which calls for large numbers of skilled staff, and which can be as costly as the spraying itself. The Congress revealed that, in many countries, appreciable areas formerly classified as malarious have passed out of routine spraying and are now under surveillance. Thailand is notable in this respect, where a population of 4.5 millions are covered by surveillance operations. In Venezuela, 469,000 people live in surveillance zones, compared with 945,000 in areas under active protection by spraying.

In addition to indicating general trends, the malaria sessions provided much valuable information on the progress of individual campaigns. It was encouraging to hear from Dr. Bruce Chwatt that, after four years of residual spraying in the Malaria Control Pilot Project, Western Sokoto, Nigeria, infant parasite rates are virtually down to zero. Dr. Marquez Escobedo explained how the disease is being eliminated from Mexico by house spraying with DDT and dieldrin, an operation employing a force of 2,000 spray men.

Although the Congress produced no panacea to dispel the threat of mosquito resistance to insecticides, it was
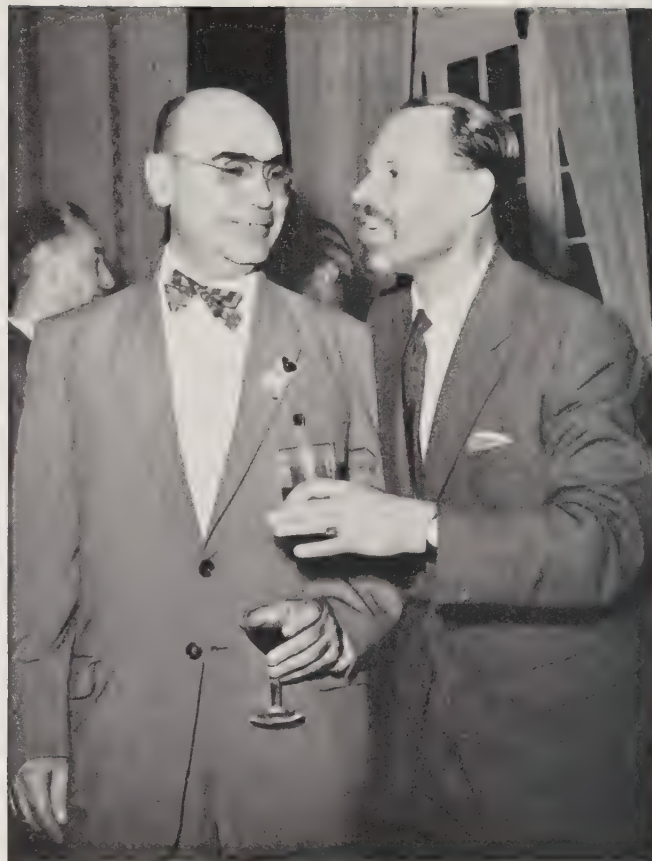
Miss Mercedes Soares (*Shell Portuguesa*),
Dr. C. W. Kearns (*University of Illinois*),
Prof. D. L. Augustine (*Harvard University*)
and Mrs. Augustine.

Dr. A. Gabaldon (*Ministry of
Health consultant, Venezuela*)
and Dr. L. J. Bruce Chwatt
(*WHO, Geneva*).

reassuring to learn from Dr. Daggy how, in Saudi Arabia, DDT-resistant *Anopheles stephensi* has been successfully controlled since 1955 with an alternative insecticide, dieldrin, and that in 1956 infant parasite rates dropped to zero, and have subsequently remained at this level.

Filariasis

Among the sessions on filariasis, papers dealing with the position in Haiti and Malaya, submitted by Dr. Kessel and Dr. Wilson respectively, were of particular interest from the point of view of disease control. An animal reservoir of a parasite, apparently *Wuchereria malayi*, has been identified at Pahang, Malaya, and threatens to complicate control of the disease. The absence of contributions on filariasis from India and Ceylon was disappointing in view of the experience gained in these countries of field control operations. In general, expert opinion appears to regard the use of diethylcarbamazine, supplemented by larvicidal attacks on the vector, as the most promising combination of control measures.

The greatest value of present-day international congresses is undoubtedly the opportunity they afford for personal contact between persons working on the same or related subjects who might otherwise never meet. The Congress at Lisbon was no exception. The 900-odd delegates included many research workers from the field and from the universities, public health administrators, members of industry and many more, and informal exchange of problems and ideas could not fail to be fruitful.

While these discussions took place mainly over meals and in breaks between sessions, an informal meeting for malariologists was arranged by the organisers to supplement the official sessions on malaria. Although this meeting, due to the need to provide a translation service, failed to achieve the informality and spontaneity of a true discussion group, the idea of unofficial meetings of specialist groups certainly merits further consideration. It is not suggested that such meetings would replace the questions and discussions which usually follow the presentation of a paper, although it would be desirable for a group discussion on a particular subject to follow closely upon the reading of any papers dealing with that subject.

It will be interesting to see to what extent the idea behind the malariologists' meeting at Lisbon is developed at the next International Congress of Tropical Medicine and Malaria five years hence.—J.A.S.

Mr. G. Davidson (Ross
Institute of Tropical Hygiene,
London), Mrs. Davidson
and Mr. K. S. Hocking
(Colonial Pesticides Research
Unit, Arusha, Tanganyika).

Dr. R. G. Aickin (Shell
Petroleum Company),
Dr. E. B. Weeks (WHO,
Geneva), Dr. A. Carradetti
(Instituto Superiore di
Sanita, Italy) and Prof. G.
Lupescu (Rumania).

Some of the delegates at
a cocktail party given
by Shell Portuguesa.

Jerseys in Kenya: winners of the Roger Ruck Memorial Cup for the best group of three females sired by the same bull; R.A.S.K. Nakuru County Show, 1957.

Britain's

Livestock

Export

Business

by **C. J. N. Stanford**

British Livestock Exports Ltd.

Highland cattle in the Andes.

The origins of most British breeds of livestock are a matter of guesswork, but almost certainly until the last 150 years Great Britain could scarcely have been called an exporter of breeding stock.

In the eighteenth century a revolution occurred in British farming methods which extended to livestock breeding. The second half of the century saw Robert Bakewell start his breeding work with Longhorn cattle and Leicester sheep. Years before the science of genetics was thought of he experimented boldly and imaginatively on principles which are still followed to this day. After Bakewell came three more brilliant men, the brothers Charles and Robert Colling, and Thomas Bates, and after them still others who spanned the nineteenth century creating defined and specialised breeds.

Simultaneously with this surge of progress new lands were opened up in Argentina, the U.S.A., Australia and elsewhere. It was, therefore, only natural that the pioneers, many of whom were British, should wish to use the improved breeds of the old country which were so superior to what were to be found elsewhere. During the nineteenth century tens of thousands of our cattle and sheep went overseas. Thus Britain became an exporter of breeding livestock and has remained so ever since.

Today there are few countries in the world where British breeds are not present in some form or other and one is as likely to see them on the slopes of the Andes as on the plains of Russia, in Quebec or in Queensland. In 1957 the United Kingdom exported breeding stock to 50 countries.

The tentacles are wide-flung and it is true to say that for temperate and semi-tropical climates, the cradle of the world's improved breeds has been Northern Europe. (We must not forget the contribution which Holland, for instance, has made with that most widespread breed of all, the Friesian.)

Only in the tropics have our breeds tried and largely failed. There are vast tropical areas in Africa, in Central America and much of South America, where beef on an extensive scale is the only possible farming economy. There the inability of our breeds to achieve rapid heat loss, and their susceptibility to the tick-borne diseases always found in hot climates, are severe handicaps. There is a wide gap between survival under somewhat artificial conditions with careful management, and commercial profitability under the rough and ready methods of beef ranching. For this reason, while our dairy and pig breeds can be kept in a pure state in the tropics, the wastage in our beef breeds would be too high.

For tropical beef production, men have turned to those tough heat-resistant breeds of Indian origin loosely called Brahman or Zebu. They still want the quicker maturity and better conformation of the British breeds and can achieve this either by outright crossing or—a more recent development—by the fusion of the British with the Brahman to form new hybrids embracing the qualities of each. Such are the Santa Gertrudis (Shorthorn × Brahman), the Brangus (Aberdeen Angus × Brahman), the Bradford (Hereford × Brahman) and the Jamaica Red (Red Poll Brahman). Thus even in the tropics our beef breeds have their uses.

With this background, what part does Britain play in the world's livestock trade? The movement of breeding animals about the world has never been so great. Holland alone exports tens of thousands of cattle a year, but

Britain's share of the total volume has diminished. The days of our bulk shipments to far destinations are all but over. Transport costs are mostly to blame for this and the basic price of our pedigree stock has been high since the war. Also a natural development has been that the other great livestock countries which we supplied in quantity many years ago have themselves become exporters to their more backward neighbours. Canada, the U.S.A., Argentina, South Africa and Australia all enjoy a large and lucrative export trade.

Quality Trade

Yet Britain still retains to a marked degree what one might call the 'Rolls-Royce' trade, and this is helped rather than hindered by the flourishing exports of the country's main markets. The world still looks to Britain for the best: the great spring bull sales at Perth and Hereford, and the agricultural shows in the summer, still bring buyers from all the great cattle countries of the world, and throughout the year there is also a constant stream of animals exported by private sale. Despite having had their first importations more than one hundred years ago, Canada, the U.S.A., Argentina and Australia are still our best and most constant customers. Their top sires in most breeds are almost always imported.

Many people wonder why these countries which have had our breeds so long and have spent so much on the best that money can buy, should still need constant refreshment. The hiatus of the war years proved this to be so. Transplant a breed from its native habitat and there results a variation from the true type which becomes more marked with each successive generation. One sees it even in the difference between Jerseys bred in their island home and those bred in England, and only fresh blood from the original source can maintain the true type.

Is it soil? Climate? Know-how? Something of each, probably, in that order of importance. The degeneration varies between countries and between breeds. In general the hotter the climate the quicker the degeneration, and British beef and pig breeds abroad need refreshing more often than dairy herds, perhaps because correctness of conformation is more important for meat production than for milk. Again, Herefords are inclined to colonise themselves more independently than beef Shorthorns. The continuity of the export trade depends on this constant need for fresh blood.

The scope for British breeds and for the country's export trade is constantly expanding, even though we have no more a monopoly of supply. The horizon of our export markets is no longer just the traditional livestock countries: the post-war era has emphasised the need to build up the agricultural resources of backward countries in which livestock improvement plays a vital part.

At last the country's own hinterland market of Europe is changing with increasing tempo to British breeds and the possibility of large-scale shipments has revived. It is perhaps curious that Europe, so near to England, has been almost the last continent to adopt our breeds. But Britain's early

progress was possible because the horse was the motive power on the farm. For centuries much of Europe has been tied to the ox for power and the sheep or the goat for milk. There is little scope to improve cattle if they have to be designed first for work and only as an afterthought to eat or milk.

The modern age is sweeping all that away. Livestock improvement is not only a matter of spending money: it goes hand-in-hand with other improvements. Better crops, better grass, better veterinary control, insecticides, fertilisers, irrigation, and above all mechanisation mean that most countries can afford to throw over their traditional all-purpose breeds and replace them with specialised and highly productive ones such as the U.K. can supply.

All countries in Europe, west or east of the Iron Curtain (except, I believe, Bulgaria) have imported British breeds since the war and some, notably Russia, Yugoslavia, Western Germany and Spain, have bought cattle, pigs and sheep on a large scale.

Export Value

What, then, is the importance to the country of the livestock export trade? Unlike its bigger cousin, the bloodstock industry, it seldom hits the headlines save when a bull is sold abroad for a five-figure price. The total value of exports for breeding—perhaps two million pounds a year—is of course negligible in the context of our world trade. But its real and special value is that most of that money is being pumped annually into the pockets of those comparatively few people on whom depend the standards of our whole livestock industry—the ever-changing aristocracy of top breeders.

It is far easier in animal breeding to march downhill than uphill, and the farther one goes uphill in one's breeding standards the harder it is to struggle up another step, and the easier to go back two. Pedigree breeding today needs not only a special flair and intelligence, but a deep pocket, a willingness to take risks and a measure of luck. It is desirable that there should be room for as many as possible on the higher slopes so that blood lines do not become too concentrated. Therefore it follows that the widest possible overseas market must be developed so that when a breeder achieves success there is sufficient sales scope for him to gain his due reward. Otherwise our breeding standards will tend to deteriorate rather than improve. Britain is too small a country for her foremost breeders to exist profitably by buying each other's stock and it is the incentive of high export prices which keeps the topflight breeders going and draws new ones to try their hands. This is the real value of the export trade, and it is one which cannot be measured in pounds, shillings and pence.

It is a business which, like other exports, is affected by world trading conditions. It flourishes in prosperity and dwindles in bad times. Yet as world living standards improve, and as more and more people rise above the floor of bare subsistence, so the scope for the country's livestock export trade must surely continue. It is possible that its greatest days still lie ahead.

Africa Fights the Tsetse Fly

by **J. E. Skinner**

Tsetse flies, *Glossina* species, are a serious menace to health and economic progress over four million square miles of Africa. They are vectors of micro-organisms of the family *Trypanosomidae* which cause sleeping sickness in man and nagana in cattle.

The relationship between the tsetse and nagana had long been recognised by African natives and was accepted by Livingstone, but it was not until 1895 that Bruce, who had been investigating a severe outbreak of nagana in Zululand, identified the causative organism of the disease, *Trypanosoma brucei*, and proved that it was introduced into the animal's body by the bite of the fly. Between 1901 and 1912, *T. gambiense* and *T. rhodesiense* were identified and proved to cause sleeping sickness in man, and their transmission was attributed to *Glossina palpalis* and *Glossina morsitans* respectively.

In the years following these discoveries much progress has been made in developing drugs and medical services to cure sleeping sickness and some measure of success with drugs has also been achieved against nagana, but since animals have far more contact with tsetse than man, the incidence of infection among cattle is many times higher and control measures are correspondingly more difficult.

Ecological methods of control have also been evolved, notably by Swynnerton in Tanganyika, who was first to develop a method of attack against the vector and to suggest a means of reclaiming tsetse infested land. During the last 10 years, increasing attention has been directed towards chemical methods of control of the fly and particularly to the use of chlorinated hydrocarbon insecticides.

The Vector and its Distribution

Of the 20 or more species of tsetse fly only a few, whose habits bring them into contact with man and domestic animals, are important as vectors of disease. They fall into two main groups, the riverine tsetse, principally *G. palpalis* and *G. tachinoides*, which live and breed in the shade of riverside vegetation, and the savannah or game tsetse, principally *G. morsitans*, which inhabit open, lightly wooded parkland, away from streams. All species require some form of tree or shrub cover. None can survive permanently in treeless grasslands and most avoid this type of country and cross it with reluctance and as quickly as possible.

Climate has an important effect on the distribution of trypanosomiasis because all species of tsetse are adversely affected by high temperature and low humidity. They tend to range more widely during the rainy season than the dry

season when they are restricted to specially favoured localities near water.

Tsetse live on blood, but there are differences in the types of blood which the various species require. The savannah species feed principally upon game animals, as well as on cattle and horses, and although they occasionally feed on birds and reptiles, they have never shown themselves capable of existing on blood from these sources alone. The riverine species can live to a greater extent on the blood of birds and reptiles.

Tsetse infestation is distributed irregularly throughout Africa from the Sahara and Sudan, southward to Southern Rhodesia and Angola. In Tanganyika, Northern Rhodesia and Uganda large stretches of territory are occupied by tsetse and are, therefore, without cattle; a similar situation exists in Kenya and Nyasaland, although on a smaller scale. Almost the whole of Nigeria and Ghana are tsetse infested, and in areas where it is practicable to keep cattle nagana causes heavy losses. Some breeds of West African cattle have a remarkable degree of tolerance to the disease but they are of poor conformation.

Control Methods

Complete extermination of the fly is impossible for reasons of cost and the immense areas involved, and even on a limited scale it is very expensive and extremely difficult. The choice of control methods is usually determined by the cost and availability of labour, but other considerations, including the species of tsetse, type of country, size of infected area, and whether infection is mainly medical or veterinary, have to be taken into account. Broadly speaking, tsetse fly control methods are either directed against the insect itself, principally by the use of insecticides, or are designed to modify its environment, by destroying its food supply, clearing vegetation which provides shelter, and then encouraging human settlement to prevent reversion and reinfestation.

Use of Insecticides

Insecticides have been used against tsetse on a considerable scale only in the past few years but techniques of application are now developing rapidly. Most of the work has been carried out in East Africa although future developments are also expected in West Africa.

During the past nine years the Kenya Veterinary Department have been studying the use of cattle as bait, and during the same period the Colonial Pesticide Research Unit at Arusha have been experimenting with aerial methods of application.

Cattle Baits. Experiments have been conducted with cattle treated externally and intravenously with insecticide. In one trial, cattle treated externally with DDT at a rate of 400 mg. per sq. ft. were grazed on infested areas at a density of 80 beasts per square mile. The applications were repeated at intervals over a period of nine months, but although adequate control was obtained the cost proved prohibitive. In other experiments aldrin and dieldrin were injected intravenously but this technique was less effective because

a significant proportion of the flies which alight rest and do not feed.

Aerial Application. Although effective control has been achieved with DDT and BHC sprayed from the air, six to eight applications have been necessary at 14-17-day intervals.

Several factors severely limit the use of aerial spraying. The right climatic conditions are critical for the success of the operation and it is only economic when carried out on a large scale. It is difficult to prevent reinfestation, and the method has been used successfully in only a limited number of areas, notably in Zululand and Uganda, which were isolated from other fly areas. Aerial applications rely on the immediate kill of flies hit by spray droplets, and do not provide any residual deposit of insecticide on the foliage. They are only effective against savannah types and cannot be used against riverine species because of the dense foliage cover, although spraying of river banks with helicopters has been attempted on a limited scale. Recently, insecticide smoke bombs have been released from aircraft. Smoke penetrates vegetation more effectively than a spray but, again, cost is likely to prohibit its use.

Aerial application of insecticides is of particular value in controlling those tsetse species which have a restricted breeding area, such as *Glossina pallidipes*. During the course of a control campaign which was started in Zululand in 1947 by R. du Toit, with the object of reducing and if possible preventing the considerable losses of cattle from nagana, it was found that the principal vector, *Glossina pallidipes*, bred in a very small area of its total range. Control of this species of tsetse fly could be achieved by spraying the breeding areas, some three per cent. of the area affected by nagana, after they had been surveyed.

The insecticides used were DDT and BHC, applied by a thermal aerosol method from aircraft. The exhaust aerosol application employed assists complete coverage of the vegetation and gives rapid penetration, even of heavily bushed areas, down to ground level where the preferred resting sites of tsetse are to be found. The time of aerial spraying was found to be important: it is obviously of advantage to apply insecticides when mass hatching has occurred and the maximum number of adults are present, and this was found to coincide with the late dry season in Zululand.

The results of the spraying operations, which lasted until 1952, were that *Glossina pallidipes* was eradicated, as was *Glossina brevipalpis* in the central part of Zululand, after eight to 10 insecticide applications. Costs were considerably less than with game eradication. The campaign was reinforced by planned game control as it was found that confining game within certain regions served to subdivide the breeding areas.

Residual Spraying. Dieldrin is being used for ground spraying of certain species of trees in savannah areas which are known to be the preferred resting places of *G. morsitans*.

The principal riverine species in East Africa is *G. palpalis*, which inhabits the densely forested regions bordering Lake Victoria and many of the streams and rivers.

The Kenya Veterinary Laboratory has for several years

An African suffering from sleeping sickness (trypanosomiasis), which is transmitted by the tsetse fly.

This picture shows clearly the emaciating effect of nagana (transmitted by the tsetse fly) on the beast on the left. The white cow, for comparison, is healthy.

been experimenting with insecticides applied as residual sprays to the habitat of the fly: the chief problems encountered have been natural leaf fall following spraying, and removal of the insecticide deposit by heavy rainfall. A successful spraying technique has been evolved. The river banks are sprayed by an operator walking along the stream bed, and in places where the river thicket is more than 60 yd. wide, the insecticide is sprayed as a narrow band on to the foliage wall of paths cut at 60 yd. intervals.

Dieldrin is being applied by this method to eradicate *G. palpalis* from an area of 300 square miles in the Kuja-Migore district of Western Kenya. Three hundred linear miles of water courses are being treated with 1.86 per cent. dieldrin spray applied four times at three-weekly intervals with knapsack sprayers. The programme started in 1956 and is scheduled to continue for three years, the final year probably being one of surveillance and consolidation.

Dieldrin is also being used in experiments to control *G. palpalis* on Sifu Island, Lake Victoria. Promising results have been obtained from a technique of intermittent spraying designed to reduce insecticide costs. Forty-yard lengths of sprayed vegetation are separated by unsprayed intervals of 60 yd. and it has been found that a mist blower (Kiekens-Dekker) gives better penetration than a knapsack sprayer. Deposits of 15-20 mg. of dieldrin per sq. ft. are obtained using this machine. This project is likely to be extended to eradicate the tsetse from all the Kenya shores of Lake Victoria.

Experiments in West Africa. Experiments with residual spraying of vegetation are being conducted in Nigeria, principally in the Azare area about 120 miles east of Kano. The principal vector is *Glossina morsitans*, which for eight to nine months of the year infests cattle grazing lands, but moves into dense river thicket with the onset of the dry season (February to May) and lives in association with the wild pig.

DDT was the first insecticide used in these experiments but because it can reduce costs and increase the length of residual control, dieldrin is being used increasingly. The tsetse appears to rest only on the bark of trees and bushes and spraying is confined to these parts. The bush is only cleared when necessary in order to approach the spraying area, the aim being to disturb vegetation and game as little as possible, so that the tsetse will concentrate in the river area during the dry season. Much more research is needed, however, into the resting habits of tsetse and the conditions under which it will survive, and it is thought now that it will tolerate a greater range of environmental conditions than was originally supposed.

Destruction of Game

Game animals are the favoured food of the tsetse and the main natural reservoir of trypanosomes, but their destruction is a subject of much controversy. It has been employed in most areas on a limited scale in conjunction with other measures, but is a policy that will not be willingly resorted to unless there is no other practical alternative.

Clearance of Vegetation

Clearance schemes have in the past represented the major line of attack against the tsetse. Total clearance of bush and subsequent settlement is the most permanent way of eradicating the fly, but it is expensive and there are obvious difficulties in resettling large sections of the population. With our increasing knowledge of the flies' habits, selective clearing has been developed involving the removal of only

those species of vegetation known to be essential to them. In the parts of East Africa where this method is being used successfully between 3 per cent. and 10 per cent. of the total wooded area is removed. Advantage is taken of natural treeless zones and these are linked either by cleared corridors or by wide belts of selectively cleared bush.

In West Africa clearing alone and in combination with insecticidal spraying is adopted along river banks, and particularly at fords, crossings and village approaches where people are likely to congregate. Barrier clearing is also practised to some extent. Lines of trees are felled across narrow river valleys and the growth of vegetation forms a barrier which the tsetse cannot penetrate or cross.

All species of fly are reluctant to cross shade-free areas, but since they are attracted by moving objects and may be carried by transport vehicles, clearings must be reinforced by inspection and 'de-flying' at crossing points. It has been found that 1,000 yd. is an economic and effective width for a clear zone. Clearing is an immense and costly task and unless the land is occupied regeneration takes place fairly rapidly.

Human Settlement

Human settlement as a method of planned tsetse control has until now been considered mainly as a means of consolidating the position after tsetse have been expelled by other methods. It has been proved that if cleared land is occupied at a sufficient density of population to drive away wild game the fly will not return. In many parts of Africa human settlement has in the past been used unwittingly as a weapon against the tsetse, the Africans themselves clearing the bush, planting crops, harrying game, and effectively driving back the flies.

The idea that settlement might be used as a positive method of tsetse eradication is now gaining favour but there are still many practical difficulties to be overcome. If human settlement is to develop as a method for simultaneously controlling tsetse and improving agriculture, people and cattle will have to be introduced into infested areas. It may be possible by wise planning and the use of modern drugs and technical and scientific knowledge to maintain a healthy human population in an infested area, but maintenance of cattle may be a more difficult problem.

Consolidation the Note at U.K. Weed Conference

One's impression that the most interesting developments in chemical weed control recently, in the United Kingdom, at least, have been in the field of new uses for established products rather than the introduction of new materials was confirmed at the fourth British Weed Control Conference which was held at Brighton last November. The conference was attended by about 400 delegates, who included representatives from 17 countries.

So far as the use of the newer weedkillers now available is concerned, the greatest interest undoubtedly lies in dalapon (control of perennial grasses), simazin (a total weedkiller, but selective in certain crops, particularly maize), CMPP (control of *Galium aparine* [cleavers] and *Stellaria media* [chickweed]) and mixtures of MCPA and 236-TBA (control of 'hormone'-resistant weeds).

An outstandingly interesting paper on the substituted triazines—of which simazin is one—was given by Dr. H. Gysin, who described the work so far carried out on determining the mode of action of these compounds. He confirmed that herbicides of this group are potent inhibitors of photosynthesis, though the correlation between this property and herbicidal activity has yet to be established.

It is no exaggeration to say that the development of chemical weed control techniques is leading to entirely new concepts of cropping and cultivation. Many traditional cultivations are based on the control of weeds, which have been an ever-present and recurring problem, and crop rotations have been designed at any rate in part to reduce weed populations associated with particular crops. Now, the use of herbicides is leading to far greater freedom of choice in cropping, and it is more than probable that many cultivations will sooner or later be dispensed with through the use of weedkillers. More than one paper at the conference focussed attention on the likelihood of dalapon's being used for the destruction of old swards which would normally come under the plough before reseeding, though at present this does not appear to be an economic proposition. Progress in chemical weed control in the international field was reviewed by Dr. E. K. Woodford (Agricultural Research Council Unit of Experimental Agronomy, Oxford), who made a strong plea for the compilation of statistical data on the use of weedkillers. He pointed out that at present it is only in the USA that reliable figures are available.

'Herbicides and the American farmer' was the subject chosen by the guest speaker, Mr. R. H. Beatty, of the Weeds Society of America. In the USA, he said, more acres are sprayed for the control of weeds than for the control of insects and diseases together. Besides reviewing some of the new chemicals at present being tested in the USA, Mr. Beatty discussed the development of invert emulsions and of the use of granular formulations of herbicides. The former, formulations of mayonnaise consistency, can, it is claimed, be applied by aircraft (using a special centrifugal sprayer) with a significant reduction in the drift hazard normally associated with conventional formulations.

Weed problems in tropical countries, particularly South, Central and East Africa, were discussed by Dr. E. R. Hattingh (Union of South Africa), who emphasised both the size and complexity of the problem of brush control and the need for more effective arboricides than are at present available.

The points outlined above impressed themselves as being highlights of the conference: they make no pretence at covering the wide range of subjects which came under discussion.—I.A.H.S.

Collecting rice for transplanting from nursery beds, in Thailand.

INCREASING RICE PRODUCTION

by **D. H. Grist,** *formerly Agricultural Economist, Malaya*

Rice is of greater importance to Asians and many Africans than wheat is to the rest of the world. While in the varied diet of the Western Hemisphere bread is now almost incidental, to millions of people in Asia and Africa rice is the main item of food, and many live on the verge of starvation because they cannot afford to buy, and are unable to produce, sufficient rice for their needs. Besides this, the demand for rice is expanding by over one million tons annually to keep pace with the increased population of rice-eating countries. It is therefore evident that in territories where rice is the staple food, the aim must be to increase local production; the following article draws attention to some of the factors involved in efforts to do so.

Over 90 per cent. of the area under rice is 'wet' paddy, grown in flooded land; the remainder is 'dry' paddy, grown without inundation. This article is concerned only with wet paddy.

Increased rice production may be achieved in two ways: by planting a larger area and by increasing the yield per unit area. For many centuries the flood plains and deltas of great and small rivers in tropical and sub-tropical regions have provided ideal conditions for paddy cultivation; not only is the soil rich in such areas, but topography allows for simple irrigation schemes. Few countries now possess large undeveloped areas of this nature, so that further extensions of paddy cultivation must be found in less ideal situations—mainly in swampy and waterlogged regions which require reclamation by drainage before they can be developed.

Many areas of this kind exist in Asia and Africa, but the cost of drainage and skilled treatment before they are rendered suitable for cultivation is in many cases prohibitive. Furthermore, many areas which at first sight appear suitable for development may be found to consist largely of peat. While the 'solid peats' are definitely unsuited to paddy, peaty soils and peats of no great depth may be developed for the crop. Frequently, however, deep peat areas may be scattered over a region otherwise suitable for paddy, thereby adding to the difficulties of drainage, irrigation and rational development.

It is clear, in view of these difficulties, that the constantly increased demand for rice must be met by increasing the yield per acre. There are several means whereby this may be achieved, such as improved drainage and irrigation, improved methods of cultivation, breeding and

Planting rice in a paddy field in Indonesia.

selection, application of fertilisers and manures, and prevention of losses caused by pests, diseases, weeds and bad storage conditions. Let us briefly examine these different possibilities.

Improved Methods of Cultivation

The assumption, so frequently made, that mechanisation of paddy cultivation is superior to traditional cultivation methods cannot be substantiated. In particular, it is claimed that mechanisation is better because it permits deeper cultivation. Depth of cultivation, however, should be governed by the nature of the soil and subsoil: generally, deep cultivation for paddy is unnecessary and may, in fact, result in decreased yields. The merit of mechanisation is that it prevents 'bottle-necks' and enables advantage to be taken of favourable weather and soil conditions.

The provision of simple, effective and cheap implements should be the aim of the agricultural engineer, for while expensive machinery makes possible the development of large areas with a small labour force, the opportunity for its employment is much restricted and rice production will for long depend mainly on the small producer.

As a means of increasing yield, the importance of transplanting paddy seedlings from a nursery to the field instead of direct sowing in the field has been emphasised in many countries. The cost in labour of transplanting is, however, very high, which restricts the practice to small holdings in areas of cheap and plentiful labour. Mechanised trans-

planting, if it were universally adopted, would result in a considerably increased production of rice. While some advance has been made towards providing a transplanting machine, further research in this direction is most desirable.

Recently, considerable attention has been directed to what is called the Japanese rice cultivation method. Adoption of the method in India is stated to result in greatly increased yields, and Malaya has recently announced the arrival of seven Japanese experts to demonstrate and give practical training in the technique. It has even been claimed that the adoption of the method by other Asian countries would lead to a world revolution in rice production.

The methods advocated by the Japanese are based on the principles of good husbandry already recognised and practised in many paddy regions, coupled with the application of modern research, such as disinfection of seed before planting, spraying against pests, and the correct application of fertilisers and manures. They also rely on great care in planting, spacing, weeding and cultivation. The introduction of the Japanese system has therefore proved most successful in countries where the technique hitherto used has not conformed with the best accepted methods.

Selection and Breeding

A field of paddy consists of plants of different types, habits and yielding power. If only the more desirable forms are

Ploughing with oxen in a flooded paddy field in Indonesia.

cultivated, yields may be increased and quality improved. There are three recognised methods by which this may be achieved—by mass selection, pure line selection and hybridisation.

In mass selection, the seed of a number of individual plants of apparently desirable characters is bulked for cultivation. Mass selection is unsatisfactory because the results are not permanent and the method offers little scope for improvement of varieties.

The aim in pure line selection is to isolate individual types which possess characters of yield and quality above the average. While such selections will breed true to type, the method is subject to the limitation that it precludes introduction of desirable characters which are not present in the original unselected paddy. Pure line selection has, however, been employed successfully in a number of countries, yields being significantly increased.

Hybridisation of paddy will prove more successful than mass selection or pure line breeding because it can provide high-yielding types and also eliminate or reduce losses from such causes as lodging, and give a high degree of resistance to pests and diseases. Favourable results have been achieved in breeding for desirable characters, but investigations have barely touched the fringe of improvements possible by this method.

Investigations on an international basis through the FAO have been made in the past few years to cross *indica* and *japonica* sub-species of paddy, with the object of obtaining progeny that inherit the desirable characters of each parent. *Indica* varieties are widely grown in the tropics, where they show great resistance to infertile soils and extreme tropical conditions. *Japonica* varieties, suited to cultivation in sub-tropical and warm-temperate latitudes, where they are capable of heavy yields, are strong-strawed, resistant to shattering and possess a great capacity for responding to fertilisers. Unfortunately, *japonica* varieties give a low yield when grown under tropical conditions, while *indica* varieties are equally unsuited to the sub-tropics and warm-temperate regions. The importance of crossing the two types is evident: it may produce varieties capable of growth in the tropics and possessing the high-yielding quality and good response to fertilisers possessed by *japonica* varieties, while retaining the hardiness and other good points of *indica* varieties. Sterility of the progeny of this cross is often, however, very high; further investigations are in progress on the causes of sterility.

Vernalisation

In order to complete its normal development cycle, seed must pass a pre-germination period under particular conditions of temperature. Vernalisation consists in subjecting pre-germinated seed to certain heat and light treatments in order to obtain normal development of the plant subsequently, even under unfavourable heat and light conditions. While the vernalisation of rice has been studied in a number of countries, it has so far failed to produce practical results;

nevertheless, the method should not be dismissed from further consideration.

Induced Mutation

Mutation appears spontaneously in paddy from time to time and may result in new varieties, some of which are of value. Mutation may also be induced artificially and there are various methods which can be employed to produce a large number of mutants. Many of these 'freak plants' will be useless, but it is possible that some will possess valuable properties, such as high yield, resistance to disease, or suitability for particular climatic conditions. As there is no control over the changes that occur in mutation the production of improved varieties by this method is, of course, a matter of chance. Nevertheless, the method offers a possible means of producing a solution to some of the problems facing the plant breeder.

Fertilisers and Manures

The position of fertilisers in paddy cultivation is somewhat confused: in some quarters it is maintained that they result in higher yields, elsewhere that no increased crop is obtained, or the increase is not commensurate with their cost. Differences in climate, topography, soil, paddy varieties and other factors probably account for these widely divergent conclusions.

Broadly speaking, 'wet' paddy is grown under three conditions:

(1) Wet tropical, where there is a firm bottom to the soil and good water control, enabling cultivation to be carried out before the land is flooded. Under these conditions the system of cultivation differs but little from that of a dry-land cereal crop such as wheat;

(2) Wet tropical, where the land is puddled for reception of seed or seedlings. The soil may be a heavy clay, a light loam or peaty;

(3) Sub-tropical or warm temperate under good, bad or indifferent irrigation and drainage control.

Under the first of the above conditions, application of fertilisers (especially ammonium salts) has generally proved successful, although experience in different regions is by no means uniform. It is doubtful whether fertilisers will pay on heavy clay under tropical conditions, where the soil is puddled before planting. Such lands, however, may respond to organic manures, green manures or organic matter plus sulphate of ammonia. Light soils give good response to ammoniacal and phosphatic fertilisers. Heavy peats in poorly drained land are usually unsuited to fertilisers. Soils in sub-tropical or warm temperate regions show a marked response to fertilisers, particularly when planted with *japonica* varieties of paddy. Specific recommendations can only be made when they are based on controlled experiments in each area.

Although fertiliser application has a part to play in increasing yield of paddy, it is impossible to estimate the potential improvement possible by this method. Much experimental work is taking place throughout the main rice areas and it is suggested that fundamental research should be conducted with radio-active fertiliser over a wide range of climatic and soil conditions, to provide information on the ultimate distribution of fertilisers in the soil and paddy plant, thereby leading to more economic methods of fertilising the crop.

Pests, Diseases and Weeds

One is impressed with the potential benefits that may result from better control of pests and diseases, and the elimination of weeds. Especially under tropical conditions, weed control is the most important function of cultivation. Oil and hormone weedkillers are destined to play a very important role in eradicating weeds from paddy fields and irrigation channels. The use of herbicides in this connection has achieved a measure of success, but further investigations are desirable because concentrations necessary to control grass weeds are of the same order as those fatal for paddy. Further investigations are desirable on the effect of modern herbicides on fish in paddy fields and water courses, which in many regions constitute an important source of food to rice eaters.

Considerable advance in knowledge of the use of fungicides and insecticides in relation to paddy has been made in recent years, but there is still much to be learned. In particular, research should be intensified to discover a really efficient insecticide to combat paddy stem borer, a pest which causes considerable damage to the crop in almost all countries. Research on prophylactic treatment against pests and diseases has received less attention than it deserves, and advances in this direction might provide a cheaper and more certain means of checking pests and diseases than methods at present advocated.

Economic and Social Conditions

Some of the more important problems of paddy cultivation have been outlined above, and many others might be added, but they are not causes of the difficulties facing the industry and their solution will not add materially to the total of rice produced on small holdings. The root causes are to be found in the social conditions of the cultivators—unsatisfactory conditions of tenancy, antiquated laws of inheritance resulting in land fragmentation, and lack of capital resulting from improvidence and ignorance.

Under present conditions most cultivators are unable to take advantage of the improvements made possible by scientists; they cannot afford fertilisers, improved implements, fungicides, insecticides, herbicides, improved seed, or better storage facilities, and until they can afford them the improvements will remain in abeyance.

To subsidise these improvements in order to bring them within reach of the cultivator will not solve the problem. Few of the improvements found possible have been widely adopted by smallholders (who, it should be remembered, grow about 90 per cent. of the world's rice) and there is little doubt that full benefit from agronomic and other improvements will not be obtained until radical changes are made in the conditions of land ownership and until the cultivator is so educated that he acquires self-reliance, a greater sense of responsibility and awareness of the problems confronting him.

Sheep Ectoparasites in Australia

by **P. Wright,** *Shell Chemical (Australia) Pty. Ltd.*

Australia's economy is based mainly on income derived from primary production, the wool industry, with its 150 million sheep, being the greatest single contributor. It has been estimated that sheep parasites cost the industry £A25 million annually in direct and indirect losses. External parasites are responsible for much of these losses and their control is of the utmost importance to the national economy.

The main ectoparasites of sheep in Australia are flies, lice and mites. The group of flies attacking sheep consists of several species of blowflies and the wingless hippoboscid parasite, *Melophagus ovinus*, commonly referred to as the sheep ked or tick. Of the lice infesting sheep, only one species is regarded as being of economic importance: this is the body louse, *Damalinia ovis*. Another parasite, the itch mite, *Psorergates ovis*, which has been causing concern to graziers is comparatively recent in its appearance as a major pest of sheep.

Sheep blowflies comprise the most important group of ectoparasites, being the only one responsible for widespread stock losses under severe conditions. There are 11 species of blowflies which attack sheep in Australia, of which *Lucilia cuprina*, the Australian sheep blowfly, and the related species *Lucilia sericata*, the European green blowfly, were both introduced into Australia, the former from South Africa or India, and the latter, as its name suggests, from Europe (9). The remaining nine species are presumed to be native insects.

Due to its widespread occurrence and unique habits, *Lucilia cuprina* has attained a role of vital significance to the sheep industry, being responsible for approximately 80 per cent. of the annual losses. The first record of *Lucilia cuprina* in Australia was in 1883 (5) but it was not reported as a pest until 1902. During the past 56 years this species has spread to all States of the Commonwealth, only appear-

ing in numbers in Tasmania as recently as 1951 (7). The other blowflies are of less importance as they are either restricted climatically in their distribution or are unable to initiate strikes.

Lucilia cuprina is dependent on the living sheep for its propagation, and, unlike the other species, carrion is relatively unimportant for its survival. Experimental work has shown that whereas less than 1 per cent. of flies bred from carrion were *Lucilia cuprina*, 90 per cent.(3) of those bred from struck sheep were of this species. For this reason control and preventive measures are, in the main, aimed at treating the living animal rather than at carrion disposal.

Although blowflies will deposit their eggs on any part of the sheep, there are three major types of recognised blowfly strike. Breech strike is annually encountered in most areas, weather conditions determining its severity. Poll strike of rams is similarly a yearly problem in many flocks, particularly where the strain of sheep predisposes rams to fighting, with consequent poll damage. On the other hand, body strike is relatively unimportant in some years, but may become most serious in seasons which are warm, humid and showery. These conditions promote bacterial growth in the wool which results in fleece rot developing. Fleece rot acts as a strong attractant to adult primary blowflies and infestation of the sheep quickly follows.

Various estimates have been made of the losses attribu-

table to blowfly attack. In 1937 the annual cost to the industry was £A4 million (1). In 1950, with high sheep and wool prices obtaining, and a bad blowfly year, the figure rose to £A10 million.

The other important ectoparasites of sheep in Australia are all obligatory parasites and cannot survive for any length of time once removed from their host. The body louse, the ked and the itch mite are responsible for similar detrimental effects on sheep. Infestation by these pests results in a general lowering of animal health and the production of a ragged unattractive fleece which has lost much of its character and brightness.

The ked (*Melophagus ovinus*) unlike the itch mite (*Psoregates ovis*) and body louse (*Damalinia ovis*) is a blood sucker and may cause anaemia in young sheep. Keds occur in most States, but are limited in their distribution to the cooler, wetter areas of the slopes and tablelands, and will generally disappear from sheep transferred to warmer dry areas such as the plains.

Itch mite, and more particularly the body louse, have a wider climatic range than keds and are distributed over most of the sheep-raising areas of Australia.

Government legislation restricting the movement and sale of infested sheep, and in some States the compulsory annual dipping of all sheep, has contributed to the suppression of these pests and it is only on a minority of properties that heavy infestations may be found.

Control

From the first appearance of blowflies as a major pest at the beginning of the century, control was mainly based on hand dressing of struck sheep. On the larger properties, losses were high, due to the practical difficulties of handling large numbers of affected sheep. Much work was carried out with the use of arsenic as a prophylactic, but this material did not achieve wide acceptance due to the laborious and unpleasant nature of its preparation and application. However, the blowfly problem was partially solved with the introduction of the Mules operation. This method of controlling breech strike was developed in 1930 and consisted of the surgical removal of strike-susceptible skin folds on either side of the breech. Removal of these folds, and the enlargement of the bare area surrounding the vulva by the stretching action of the healing wounds, resulted in the loss of attraction of the blowfly to this site.

It was not until a further 10 years had elapsed that the first full-scale demonstration of the effectiveness of this operation was carried out. In 1939-40 (4), 10,000 merino sheep were Mulesed whilst a group of 8,000 similar sheep were kept as the controls. The incidence of breech strike in each group was carefully recorded. At the conclusion of the trial the test group showed a strike incidence of 1.2 per cent. compared to 135 per cent. in the untreated controls.

Modifications have been made to the original operation and it is now widely accepted that Mulesing, with judicious crutching, will control breech strike under most conditions. Unfortunately there still remains the problem of breech strike in young sheep before the operation, in older sheep

which have not been treated, and in lambing ewes. In these circumstances reliance is placed on insecticide application.

Before the introduction of DDT and BHC into Australia in 1946, control of lice, keds and itch mite had been based on the use of dips containing arsenic, rotenone and lime sulphur, either separately or in combination. With the advent of the chlorinated hydrocarbons, there began a new era in ectoparasite control. Both DDT and BHC were effective in controlling blowflies, although their residual effects were limited, and their costs high. They both controlled lice and BHC was effective against ked and had a suppressing effect on itch mite. BHC gained wide usage as a general ectoparasite controlling material, whereas DDT became the main insecticide used in blowfly-strike dressings.

Low Cost Protection

In 1954 dieldrin and aldrin became commercially available in Australia and the experimental work that had been conducted with them for ectoparasite control during the previous two years could be realised. For blowfly control there could be offered products which would give protection, against body strike, for 16-18 weeks at a cost of one to two pence per sheep. In 1955 came the wide acceptance of aldrin and dieldrin for blowfly strike prevention and control, and in this year dips for lice and ked control were developed.

The appearance of blowflies resistant to dieldrin and aldrin in several isolated areas in New South Wales was recorded towards the end of 1957 (8). Widespread publicity associated with this occurrence resulted in a decline in the demand for these insecticides for blowfly control, but most authorities agree that both will remain effective in most areas for at least several years and recommend their continued usage unless resistance is established on the particular property concerned.

Like other commercially available chlorinated hydrocarbon insecticides, aldrin and dieldrin do not control itch mite, and there is now a tendency to use arsenic and/or lime sulphur for this purpose; in some cases dips are being used which contain one or other of these materials in combination with aldrin or dieldrin.

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A newly emerged male sheep ked, Malophagus ovinus.

A sheep blowfly, Lucilia *sp*.

An adult sheep body louse, Damalina ovis, *enlarged*.

An adult female sheep itch mite, Psorergates ovis, *much enlarged*.

American Law on Pesticide Tolerances

by **R. E. Hamman,** *Shell Chemical Corporation,* U.S.A.

In the United States, a law known as the Miller Pesticide Residue Amendment of the Food, Drug and Cosmetic Act—better known as the Miller Bill—was enacted in 1954 in order to control the extent of pesticide residues present in raw agricultural commodities, by setting tolerances for their presence on individual crops. In the following article the author discusses the provisions and consequences of this Act.

During the growing and processing of foodstuffs various substances are added which can be classified as adulterants under the following definition: 'Adulterate: to prepare with an ingredient included which is not part of the professed substance'. Adulterants may include such things as pesticides, food preservatives, colorations, etc. Such materials may range from being harmless in any quantity to the health of those consuming the foodstuff, to being detrimental to a person's well-being, either acutely or chronically, depending on the quantity or characteristic of adulterant present.

In an attempt to define 'adulteration' as it pertains to pesticides, the Miller Pesticide Residue Amendment of the Food, Drug and Cosmetic Act, better known as the Miller Bill, has been enacted in the United States. This law, as it relates to pesticides, establishes residue tolerances for food crops, thus providing a maximum amount of residue which legally may remain on or in the food crop at harvest.

The Miller Bill divides pesticide chemicals into the following categories:

(1) Those which do not come within the law;
(2) Those which are exempt from the requirement of a tolerance;
(3) Those which require a tolerance;
(4) Those which require a zero tolerance.

It should be noted that a pesticide requires a tolerance only on those crops where a residue remains.

Basically, two steps are required in the setting of a tolerance for a pesticide on a crop: first, the determination, by study of toxicological data on animals, of a maximum residue which will not be harmful to the consumer. And, secondly, the establishment of a practical dosage rate and time interval between last application and harvest which will result in a residue equal to or less than the allowable maximum residue.

The purpose of the law is to keep residues at a minimum consistent with effective use. Therefore, a tolerance is set at a level no higher than necessary, irrespective of the maximum safe residue as determined by toxicological studies. For example, the safe residue level may be determined as 7 p.p.m. for a given pesticide. However, if the

dosage rate and time interval which give practical results in the field leave only 3 p.p.m. on the crop at harvest, the tolerance for that particular crop could be set at 3 p.p.m. By this criterion for setting tolerances, it is conceivable that a pesticide could have a different tolerance on every crop.

There has been a tendency in the past to compare the toxicity of pesticides by the tolerances granted. From what has been said above, it can be seen that tolerances granted and relative toxicity need not have any direct relationship. The purpose of the law is to keep residues on crops to a minimum. A highly toxic material which leaves minute residues on foodstuffs (and therefore is granted a small tolerance) can be just as safely ingested as a relatively non-toxic material which leaves large residues on crops (and therefore is granted a large tolerance).

Of major importance in considering tolerances is the fact that when a tolerance is set for a pesticide on a crop the residue remaining is within safe limits, and that no greater residue need be present when the dosage rate and time interval between last application and harvest are observed.

A second misconception concerning the Miller Bill has been the idea of some that a pesticide cannot be used on a certain crop until a tolerance has been established on that crop. The setting of a tolerance, with the exception of a zero tolerance, is necessary only when a residue remains after proper usage. A residue may not remain, for instance, when the use of a pesticide occurs at such time that the edible parts of the crop have not begun to form; no residue could be present (systemics excepted) and therefore no tolerance need be established. Under these conditions, non-establishment of a tolerance for a pesticide registered and accepted for use means that the material is being used under the safest conditions, rather than that the material is too toxic for a tolerance to be established. A zero tolerance can also have another connotation as will be discussed later.

The user of a pesticide need not know the tolerance (or lack of need for a tolerance) established by law as long as he follows the directions for use on the label of the product. If he exceeds the dosage rate and/or shortens the time interval between last application and harvest, an excessive residue beyond that allowable by law could result, and his crop would then be liable to confiscation. Directions for use must be carefully followed.

Pesticides Classified

The discussion so far has principally covered the majority of pesticides which require the establishment of tolerances. As has already been pointed out, certain pesticide chemicals are further divided into: (*a*) those which are not included under the Miller Amendment; (*b*) those which are included but are exempt from the requirement of a tolerance on certain crops; and (*c*) those which should not be used under conditions that will leave any toxic residues on fruits or vegetables for market—i.e., those given a zero tolerance.

In the first of these categories (*a*) are placed sulphur, lime, lime-sulphur, potassium polysulphide, sodium carbonate, and sodium polysulphide.

The second category (*b*) comprises the following pesticide chemicals, which are exempt from the requirement of a tolerance when they are applied to growing crops in accordance with good agricultural practice:— the following copper compounds: Bordeaux mixture, copper acetate, basic copper carbonate (malachite), copper-lime mixtures, copper oxychloride, copper silicate, copper sulphate basic, copper-zinc chromate and cuprous oxide; also Allethrin (allyl homologue of cinerin I) on beans, broccoli, brussels sprouts, cabbage, cauliflower, collards, horseradish, kale, kohlrabi, lettuce, mushrooms, mustard greens, radish, rutabagas, and turnips; N-Ocytylbicyclo-(2,2,1) — 5-heptene-2,3-dicarboximide; petroleum oils; piperonyl butoxide; piperonyl cyclonene; N-propyl isome; pyrethrum and pyrethrins; rotenone or derris or cube roots; ryania; and sabadilla. These pesticides are not exempted from the requirement of a tolerance when applied to a crop at the time of, or after, harvest.

This second category also includes the following pesticide chemicals which are exempt from the requirement of a tolerance when they are applied to raw agricultural commodities after harvest in accordance with sound agricultural practice: carbon disulphide (exempt when used as a post-harvest fumigant on barley, corn, oats, popcorn, rice, rye, sorghum [milo], wheat); ammonia (exempt for post-harvest use on grapefruit, lemons, oranges); carbon tetrachloride (exempt when used as a post-harvest fumigant on barley, corn, oats, popcorn, rice, rye, sorghum [milo], wheat); ethylene dichloride (exempt when used as a post-harvest fumigant on barley, corn, oats, popcorn, rice, rye, sorghum [milo], wheat); and ethylene dibromide (organic bromide residues exempt when used as a fumigant on barley, corn, oats, popcorn, rice, rye, sorghum [milo], wheat). A tolerance of 50 p.p.m. of inorganic bromide residues (calculated as bromine) from ethylene dibromide has been set on the same crops.

Zero Tolerances

Under the 'zero tolerances' category (*c*) come the following poisonous or deleterious substances, which should not be used under conditions that will leave any toxic residues on fruits or vegetables at harvest: calcium cyanide (tolerances established for certain uses; see under specific crops); dinitro-O-cresol; hexaethyl tetraphosphate; mercury-containing compounds; hydrocyanic acid (tolerance established for post-harvest use; see under specific crops); selenium and selenium compounds; and tetraethyl pyrophosphate. These 'zero tolerances' are from the 1950 hearings.

Many uses of pesticides leave no residues when the pesticides are applied as directed. Where no residue results from a certain use of a pesticide, it is not necessary to obtain a formal tolerance. However, this has been done in some instances and a number of 'zero tolerances' have been established because no residues result from use of the pesticides according to directions. All pesticides with 'zero tolerances' or without numerical tolerances (exempt pesticides excepted) should be used only under conditions which leave no residues in or on raw agricultural commodities at harvest. For detailed information on specific pesticides the manufacturer should be consulted.

Books

THE TEA INDUSTRY PORTRAYED

Tea.

T. Eden. Longmans, Green & Co., London. 35s.

Tea is published as the third in a series of books on tropical agricultural subjects which is being sponsored by the Colonial Advisory Council of Agriculture, Animal Health and Forestry. The aim of the series is to present an up-to-date, authoritative survey of a particular crop or industry by an acknowledged expert, covering most of the tropical and sub-tropical countries where the crop is grown or the industry carried on.

Without doubt, Dr. Eden is in a unique position to present to the reader a world-wide picture of the tea industry. Following his departure from the Tea Research Institute in Ceylon, where he had been Director, Dr. Eden went to Kenya as Director of the newly formed Tea Research Institute at Kericho. Although he has now retired from this post, he still retains his interest in the tea industry as a consultant.

In this book the author has presented a closely reasoned account of the growth of the tea industry over the past 150 years, and has shown how scientific research has been allied with the skill and observation of the planter to solve the many problems involved in planting, pruning, plucking, manufacturing and marketing the 'two leaves and a bud' which commerce takes from the bush, *Camellia sinensis*.

Although written from the viewpoint of the scientist, this book will nevertheless be of great interest to the planter for its comparison and commentary on planting practices in the various main tea growing areas of the world.

The author's treatment of his subject follows a series of logical steps. He begins with a discussion of the geographical origin of the various sub-species of tea, and continues with a very clear exposition of the reasons for tea being best suited to the particular soil types found in certain climatic regions. The chapter on taxonomy gives much food for thought on the characteristic periodicity of growth shown by tea, and on the ways in which this knowledge can be used to achieve proper control of the frequency of plucking. It is likely to be some time, however, before the mathematical expression derived for the periodicity of growth enables the planter to calculate his plucking rounds by slide rule rather than by observation.

The chapters on planting up tea land, and on the operations of plucking, pruning, cultivating and manuring are somewhat more broadly covered, and here the interest lies in a comparison of the variations in field practice between various tea growing areas, and on the volume of scientific work which has been done to support or amend the practical techniques that have been worked out by the industry itself.

The chapters on the various pests and diseases affecting tea cover the subject well, though the accent understandably is on the Ceylon and North Indian tea growing districts, where most work has been done by the research stations. There is, however, a somewhat disappointing lack of detail on the various control measures which can be employed.

Two very interesting chapters are devoted to the practices of manufacture. The chemistry of fermentation is considered in detail not often found outside the more technical articles in scientific journals. Dr. Eden also discusses recent developments in the manufacture of non-wither teas—although one suspects that the last word has yet to be said on the quality of the made teas produced by these newer methods.

In the final chapters the author explains some of the mysteries which are generally believed to surround tea-tasting and the buying and selling of teas at auction. There is a useful section giving the statistics of production in all the main tea growing

areas of the world up to 1955. The book is completed by a comprehensive index, though it lacks a glossary of technical words, which would have widened its value to the non-scientist reader. There is a large number of excellent photographs and the diagrams throughout the text are of great value—indeed they are essential to a clear understanding of the book by those who have not worked in the tea industry. For the scientific worker, the list of references provided at the end of each chapter is an excellent aid to following in greater detail points of interest raised in the text.

We must be grateful to Dr. Eden for providing an authoritative account of an interesting crop and a most important industry.—G. S. PAYNE.

"SANDERS" REVISED

An Outline of British Crop Husbandry.

(*Third Edition, 1958*).

H. G. SANDERS. Cambridge University Press. 35s.

Few people connected with agriculture in Britain will be unacquainted with Professor Sanders and *British Crop Husbandry*. In fact this first sentence must recall to hundreds of minds a very rare pleasure in reading for examinations, for to read Sanders was not to cram but to absorb a philosophy and, as the principles of arable farming were revealed, to wander in imagination over newly cultivated fields and through growing crops. None of these pleasures has been lost in reading the third edition. The emphasis has changed as recent advances have been incorporated. As the author states in his preface, new materials and new

methods have become available to the farmer over the last ten years, but nothing has occurred to change fundamental principles. It is these principles which are so well discussed and described; details of the agronomy of individual crops are not given, for such is not the purpose of this book.

The opening chapter deals with the subject of crop rotations—still a vital consideration to-day—for while there is an increasing tendency to break away from fixed rotational cropping this can only be done with reasonable safety provided that the principles of crop rotation are fully understood, and even then not always with impunity. In the following chapter on manuring, revisions have been made. Farmyard manure is given its rightful place at the beginning and thereafter the effects of nitrogenous, phosphatic and potassic fertilisers, the use of compound fertilisers, unit valuation and the time and methods of application of chemical manures are discussed. Here the term 'fertiliser' might have proved more acceptable to some than 'chemical manures'.

Weed control immediately suggests spraying and the use of selective herbicides. This aspect is dealt with under the heading of cleaning but is rightly stressed as only one weapon, admittedly a very powerful one, in the fight against weeds. The policy throughout the book is 'first things first', and the importance of cultivations in weed control is given full weight.

Two chapters are devoted to the subjects of tillage and the requirements and preparation of seedbeds—aspects which do not always receive their full share of attention, fundamental as they are to crop production. In succeeding chapters further principles of crop production are discussed, from the choice and treatment of seed, sowing, after cultivations and harvesting, through to storage and marketing. Naturally the principles have been sieved according to the crops, whether cereals, potatoes, or sugar beet. The final chapter on costs is understandably brief in view of the uncertain value of theoretical estimates. A comprehensive index makes reference easy.

An Outline of British Crop Husbandry is generally regarded as

a standard text book for students of agriculture: as such it excels, but it is more, and could be read to advantage and with interest by those concerned with land management in any form, by those only remotely connected with agriculture or by those interested, whether involved or not, in rural life.—J. D. IVINS.

METEOROLOGY FOR THE FARMER

Farming Weather.

L. P. SMITH. Nelson, London. 15s.

Included in Nelson's Agriculture Series, this book is designed as a plain exposition of those parts of meteorology and climatology of which knowledge is required by practical farmers. It falls into three main sections.

The first section, 'The Weather', deals with topics such as the ways in which the earth's surface is heated and cooled; with the distribution of wind and humidity near the earth's surface; with explanations of fog and frost; with factors governing soil moisture and temperature; and with the effects of weather on the distributions of pests and diseases. The emphasis given to different topics varies with their relevance to the farmer: thus, the effect of the earth's rotation in deflecting winds and the mechanism by which cloud droplets are thought to become rain drops are ignored, while topics such as fog, which may be of great significance to the industrial life of the nation, are not stressed as their effects on farming are smaller.

Many of the topics discussed are really micro- or near micro-climatology, but these are of the greatest importance in farming. Among them are considerations of such things as the incidence of frost on different types of soils, the variations in diurnal heating of soils, the variations in moisture content of soils caused by the soils themselves, the rain falling on them and the methods by which they are cultivated, and the effects of removing hedges and planting windbreaks. The author discusses these subjects in a light but comprehensible fashion. He is careful to point out that, although the factors quoted above affect the growth of crops, these effects cannot be quantitatively assessed; he is honest about points which remain obscure through lack of meteorological or farming knowledge, and scathing about the reasons advanced for some operations, such as the reduction of evaporation said to be caused by hoeing or harrowing.

The second part of the book, 'The Climate', is concerned principally with seasonal variations of climatic elements over the British Isles, but this goes beyond such obvious things as seasonal extremes of temperature. It considers such effects as accumulated temperatures, average dates for the start and finish of the growing season, sunshine totals, rainfall variability and intensity, seasonal deficits of rainfall, and ends with a brief discussion on whether our climate is changing. As in the first section of the book, the emphasis is on the relevance of the climatic factors to the farmer.

In the final section, 'The Forecasts', the author critically assesses the value of forecasts of varying periods, frankly faces the fact that forecasts go wrong occasionally—especially through mistiming of rates of movement of pressure systems and fronts—and pleads for a better appreciation of forecasts. The layman usually judges a forecast on the occurrence of rain. It is impossible to forecast the exact positions of convectional showers, so

that the lack of such showers at one locality when they were forecast for a region is often said to make the whole forecast wrong, in spite of the fact that the forecast winds, cloud cover and visibility were perfectly correct.

Some sound advice on the type of information that can be expected from a weather forecast is included. The book ends with a collection of some of the more accurate sayings about weather.

As a whole the book is written with a light touch that makes it very readable. At the same time it is not over-simplified and the complexity of relations between weather, soil and plants is stressed. It is full of interesting information and should prove a very useful book, not only to the farmer, but also to the student of geography attempting to link physical and human geography via micro-climatology and agriculture. It is illustrated by a number of clear line diagrams and by a number of poor, fuzzy plates, but fortunately the latter are not essential to the understanding of the text. The reproduction of the plates of clouds suffers especially and it is difficult to see the differences between some of them. The use of quotations at the beginnings of chapters seems slightly odd in a book of this light style, while the initial injunction, 'Get mud on your boots', positively antagonises one! But the general excellence of the book soon compensates for the mud.—B. W. SPARKS.

APHIDS IN EAST AFRICA

A Study of the Aphididae (Homoptera) of East Africa.

V. F. EASTOP. Colonial Research Publications, H.M. Stationery Office, London. 27s. 6d.

This book relates to aphids found in Kenya, Tanganyika Territory, Uganda, Pemba and Zanzibar and mention is also made of species occurring in Sudan, Somalia, Nyasaland and neighbouring regions. Prior to the publication of this work the aphid records that existed for this region were scattered rather widely in entomological and agricultural literature. Mr. Eastop has performed a most valuable service in bringing this information together into one book.

At the present time interest in the biology of aphids is growing and many fertile new ideas are being advanced. Inevitably all such work ultimately requires a sound basis of systematics and taxonomy and the appearance of books such as this is welcomed by aphidologists.

In the introductory chapter the author deals rather briefly with some general features of the systematics of aphids, the indigenous aphids of the region, the occurrence of sexual forms, aphid flight, collecting and preserving techniques, terminology and morphology. There then follow sections on the five sub-families, *Aphidinae, Callipterinae, Lachninae, Thelaxinae* and *Eriosomatinae*. Keys are provided to separate these sub-families as well as the tribes, genera and species which comprise them. Illustrations of some key characters are provided towards the end of the book while a short note and accompanying figure explain the terminology and abbreviations used. This taxonomic section is followed by a useful list of the host plants of the species described, which should be of interest and great use to non-specialists. There is an excellent reference list occupying

some 10 pages and this is followed by an index of generic and trivial names.

Although primarily meant for the specialist entomologist this work should undoubtedly find its way on to the library shelves of every agronomist interested in the east African region, because besides its purely taxonomic aspect mention is also made of what biological information exists about the various species included—for example, virus transmission, host plants, geographical distribution, etc. It is perhaps unfortunate that room was not found for a fuller account of such an important subject as aphid flight and migration, though the reader is given references to papers on this aspect of aphid biology.

The section on collecting and preserving techniques could with profit have been very considerably extended. While it is true that an outline is given of current methods of preserving aphids, how much more valuable would it have been to have treated this aspect in greater detail for the benefit of those who are not aphid specialists but who may, nevertheless, find it necessary on occasion to collect and preserve specimens. Upon such non-specialists the author and other systematists must depend to some extent for supplies of further material. Nothing is more annoying than to have valuable specimens rendered well-nigh useless because of bad preservation.

These are, however, minor criticisms of an extremely useful book. It is well printed on excellent paper and maintains the high standard of production associated with H.M.S.O. Mr. Eastop is to be congratulated on this useful and timely addition to aphid literature.—A. R. HILL.

PESTICIDES AND LIVESTOCK

Veterinary Toxicology

(formerly *Lander's Veterinary Toxicology*).

R. J. GARNER, M.A. (Cantab.), M.V.Sc., F.R.C.V.S., A.R.I.C.

Bailliere, Tindall and Cox, London. 35s.

Toxicology is an untidy, interesting and vastly important subject of great practical significance in human and in veterinary medicine. For many years the more classical inorganic substances such as lead and arsenic, and a variety of naturally occurring plant poisons such as strychnine have formed the basis for the study of veterinary toxicology. Such information has been elegantly summarised in Nicholson's 1945 Edition of Lander. Since then the subject has expanded enormously because of the introduction of a wide range of many new and complex organic pesticides.

Although Mr. Garner's work retains some similarities with the 1945 edition of *Lander*, it is practically a new text book.

As the author states, there are many changes. Among these may be mentioned a new section of about 50 pages on the pesticides, relegation of analytical techniques to a separate section and deletion of the botanical diagrams. The book—now 415 pages—contains a mass of useful information with adequate representative references and a good index. Obviously at the commencement of any work of this kind the author must face the invidious choice between what to put in and what to leave out, and Mr. Garner seems to have arrived at a reasonable compromise.

The book is likely to appeal to a fairly large number of readers, and it is good to note that the author has included many references to human toxicology—e.g., DNC poisoning—since all efforts to interweave veterinary and human medicine can result only in great mutual benefits.

In dealing with the various Parts into which the book is divided, some comments are offered. The introduction includes much useful information in enunciating general principles. Possibly the definitions of a poison are rather laboured, since it is obvious, if not universally appreciated, that any substance can, under certain circumstances, act as a poison, whereas the comments on accumulation and elimination are slightly over-simplified. In considering accumulation it must be remembered that the effects caused by a poison may persist even after its detoxication and elimination, and therefore association of the definition with the poison alone is insufficient. Further, the division of poisons into groups which are slowly and rapidly excreted is too sweeping.

The section on pesticides is clearly set out and the author has managed to summarise a great deal of reasonably up-to-date information into a relatively few pages. The approach in dealing with this new group of chemicals is by classifying them according to their use. This is a reasonable approach in view of the impossibility of classifying according to chemical structure or biochemical effects.

The section on dinitro compounds contains most of the relevant information, and that on the organo-phosphorus insecticides is an adequate summary of a mass of complex information on an expanding series of substances. In dealing with diagnosis the author concentrates on the estimation of red cell cholinesterase. This is not a particularly reliable procedure when only one sample is available, and when exposure to the insecticide is slight. Surely, this is not the only approach and would appear to be contradicted by a previous statement that 'the rapidity with which signs of poisoning follow exposure to the insecticide depends on whether the compound is a direct inhibitor of cholinesterase or not'. It is also unfortunate that the author has mentioned that the end products (e.g., *p*-amino-phenol glucuronide) of parathion are easily detectable, for a large number of these substances in this group now in use do not possess such easily identifiable groups—in fact most of them are extremely difficult to detect by chemical methods.

All this emphasises the need for the most careful clinical approach and observation in the diagnosis of poisoning. It is most unfortunate that the development and utilisation of so many new and valuable analytical techniques in the medical sciences seem to have replaced to a large extent the ability to observe carefully, without many external aids, the subtle clinical changes in a patient, whether a man or an animal.

In spite of the deletion of the botanical diagrams the Part concerned with poisonous plants has been well treated.

Throughout the book detailed chemical formulae have been kept to a minimum—probably a wise decision—and the classification is correctly according to Engler and Diels.

The final part is devoted to toxicological analysis, but it is doubtful whether this should have been included at all. After all, the busy veterinary surgeon will not have the time or the facilities to perform even the most simple tests, and the expert toxicologist will have both information and facilities available to him that are superior to those found in this section.

In spite of all the definite and confident information contained in the pages of this book, there is still a multitude of problems that require urgent investigation: two immediately come to mind: first, what is the effect of various poisons on the metabolism of the rumen flora and fauna, and the subsequent effects on the host? And what tests can be devised to identify the earliest signs of mild chronic poisoning? There is no doubt that

in the course of time much will be done to solve these and many other problems that face the toxicologist and the clinician.

Despite these detailed criticisms, however, this rebuilt *Lander* is a worthy successor to its predecessors and should prove a useful *vade mecum* to all those who are interested in applied veterinary toxicology.—D. G. HARVEY.

THE PROBLEM OF RESISTANCE

Insecticide Resistance in Arthropods.

A. W. A. BROWN.

World Health Organization, Geneva, 1958.

Monograph Series, No. 38. Pp. 1-240. 25s.

The discovery of the insecticidal properties of DDT inaugurated a new era in the control of arthropod pests—the era of the synthetic organic insecticide. DDT was soon followed by γ-BHC, the *cyclo*diene derivatives, analogues of the natural pyrethroids, and a whole range of organic phosphorus compounds. These new compounds promised a virtually complete control of the major species attacking crops or transmitting disease. Much of this progress, unfortunately, is now very seriously threatened by the problem of insect resistance to many of these insecticides which is sometimes so spectacular as to involve virtual immunity of the pest and the complete loss of effective control in the field.

The urgency and global nature of the problem in relation to insect vectors of disease such as malaria and typhus has been recognised for some years by the World Health Organization and by the appointment of Professor A. W. A. Brown as biologist in 1956. During his term of office Professor Brown has encouraged, co-ordinated and even participated in almost every aspect of research on the problem in a manner which has commanded the respect of all his fellow workers. His monograph on arthropod resistance displays an erudition and authority on the subject which could be derived only by a combination of the uniqueness of the author's position and his personal industry and enthusiasm.

This monograph is the most comprehensive review of the subject yet to appear, though it is by no means an exhaustive review and, as explained in the preface, there is a distinct emphasis on resistance in insects which directly affect man and animals. While this is a proper emphasis for a publication of the World Health Organization it might perhaps have been usefully indicated in the title or in a sub-title. For example there is no mention of the serious levels of resistance to the chlorinated hydrocarbons, reported in 1957 to have developed in the cotton boll-weevil infesting the larger cotton-growing area of Louisiana. Similarly there is no discussion of the economic implications of the resistance problem from the points of view of agriculture or the insecticide industry.

Four chapters deal with the genetic nature and development of resistance, resistance in species which are vectors to man, what is known of the physiological and biochemical mechanisms of resistance, and resistance in species which are not vectors.

The first chapter describes the historical development of resistance in vector species, the public health implications, the genetic nature of the inheritance of resistance, and the important problem of detecting significant levels of resistance in field populations. The second chapter deals *seriatim* with case histories of the vectors such as body lice, and mosquitoes transmitting malaria and yellow fever. The third chapter deals mainly with the housefly since much the larger part of systematic research has been conducted with this insect. The final chapter, like the second, deals with case histories of the field development of resistance in fruit flies, bed bugs and cockroaches.

The work makes salutary reading. Nearly 700 scientific papers and communications on the resistance problem have been published. In perhaps one case alone, that of the resistance of the housefly to DDT, can any claim be made to understand the mechanism of resistance in such a way as to suggest an effective countermeasure. In no case has a satisfactory countermeasure been developed except the unavoidable change to an alternative insecticide. It is nevertheless equally clear that a solution to the problem is unlikely to emerge except as the result of continued research and development. This solution may indeed involve entirely new concepts in the field of pest control.

Professor Brown has wisely refrained from speculating about the future of the resistance problem and the possible development of countermeasures. There are, indeed, grounds for believing that rational solutions to the problem, at least in certain cases, may be achieved as a result of further research and development. The alternate use of negatively correlated insecticides is an example, but largely a theoretical one it must be admitted, and one based as yet on meagre experimentation.

In his understandable desire to draw as late as possible from current laboratory research the author has perhaps allowed too many important statements to be based on 'personal' or similar communications so that here and there a premature statement has received a little more publicity than it deserved. This in no way alters the fact that Professor Brown has done a splendid service in reviewing the subject and it can be recommended as fascinating reading to all interested in chemical control and as an essential text to those actively studying the problem.— F. P. W. WINTERINGHAM.

TROPICAL VADE MECUM

A Note Book of Tropical Agriculture.

(*6th Edition*).

Imperial College of Tropical Agriculture, Trinidad, B.W.I 12s. 6d.

This useful pocket book, an 'old faithful' of many colonial planters, has been completely revised by the ICTA staff; it has been brought up to date and contains much new information. Chapters have been added on dairying—the information on livestock now comprises some 70 pages out of about 250— grasses and agricultural chemicals. A very useful list of reference books (mainly crop monographs) has also been added. In a book of this type, which is intended to cover tropical agriculture in the broadest sense, it is easy to find statements with which one disagrees: in modern clonal rubber plantings, for instance, a man surely taps more than 200-300 trees a day. One could also wish for more practical detail in some sections, and on pest control more guidance on application methods and machinery, especially with regard to labour requirements, would be useful. Nonetheless, this is an extremely practical book whose revision will be welcomed by farmers and planters.— A.M.H.S.

Ten fingers, one hand

In the deep-clefted, luxuriant valleys of Moyenne Guinée, the soil is warm and moist and rich in humus, and green fingers grow ten, twelve, twenty to the hand. Here, as in Basse Guinée also, everything is perfect for banana growing. Or so it would seem.

Yet where once bananas grew readily, averaging 40-50 tons per hectare (16-20 tons per acre), a strange inexplicable decline set in and yields began to fall steadily. Fertilisers were tried, and, for a time, the plants revived—only to relapse again to give even lower yields. For the planters —and for the future of Guinée as France's largest supplier—the outlook seemed bleak. And then at last the cause was found: *Nematodes.* Eelworms of minute size—swarming unseen and almost invisibly in the soil, voraciously attacking the roots. But controllable, as events have now proved, effectively *and without damaging either young or established plants*, by Nemagon, developed by Shell.

Injected at a rate of 35-40 litres per hectare (3-3½ Imperial gallons per acre), this powerful Shell soil fumigant destroys the attacking nematodes, resulting in hitherto unattainable plant growth and productivity. In a trial on heavily infested soil in Guinée, banana yields increased *fourfold*. In exceptional circumstances, Nemagon treatment may boost yields to 60-70 tons per hectare (24-28 tons per acre). In addition, harvests come earlier, giving *an extra crop* every 3-4 years. *All round, Nemagon is certainly a helping hand to growers of 'green fingers'—and of many other important world crops also.*

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